# SEWAGE WORKS JOURNAL

VOL. IX SEPTEMBER, 1937 No. 5

## *Special Articles*

Sewer Maintenance—Olewiler

Chemicals at El Paso—Yaffe

Wastes and Sludge Digestion—Rudolfs

Digestion Gas for pH Adjustment—Chujo

Ohio Data on Per Capita B. O. D.—McDill

Operators' Discussions in Ohio, Michigan and Iowa

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Publication Office: Prince and Lemon Sts., Lancaster, Pa.

Editorial Office: 910 So. Michigan Ave., Chicago, Ill.

Subscription Price:

Members of Local Sewage Works Associations affiliated with the Federation, $1.50 per year.

Non-members: Total fee $3.00, which includes subscription at $2.00 and service information fee of $1.00; Canada, $3.50 per year; other countries, $4.00 per year.

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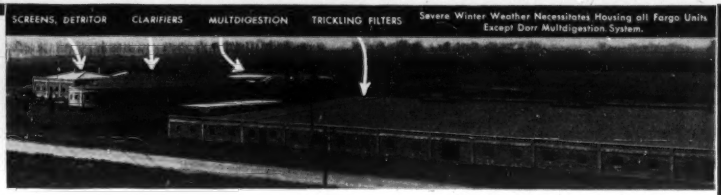


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| | | |
|---|---|---|
| **Population** | Designed for | 40,000 |
| | Actual Contributing | 28,000 |
| **Raw Sewage Flow** | Designed for—m.g.d. | 3.00 |
| | Present—m.g.d. | 2.13 |
| **Raw Sludge** | Moisture—percent. | 96.6 |
| | Volatile Solids—percent. | 71.0 |
| | Ash—percent. | 29.0 |
| **Primary Digested Sludge** | Moisture—percent. | 90.44 |
| | Volatile Solids—percent. | 40.5 |
| | Ash—percent. | 59.5 |
| **Secondary Digested Sludge** | Moisture—percent. | 74.2 |
| | Volatile Solids—percent | 38.3 |
| | Ash—percent. | 61.7 |
| **Reductions—Primary** | Solid Matter—percent | 51.3 |
| | Volatile Matter—percent. | 72.2 |
| **Secondary** | Solid Matter—percent. | 53.0 |
| | Volatile Matter—percent. | 74.7 |
| ****Gas Production** | Per Day—cu. ft. | 29,040 |
| | Per Capita Per Day—cu. ft. | 1.04 |
| **Overflow Liquor** | Total Solids—percent. | 0.21 |
| | Suspended Solids—p.p.m. | 409 |
| ****Digester Temperatures** | Primary—Fahrenheit | 90° |
| | Secondary—Fahrenheit | 79° |
| **Primary Digester Loading** | lbs. of dry solids per cu. ft. per month | 1.69 |

** July 1936 to January 1937 Inclusive*
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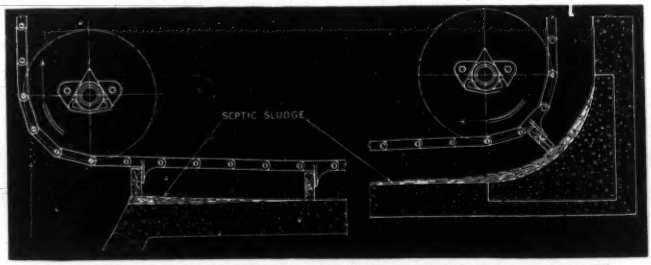


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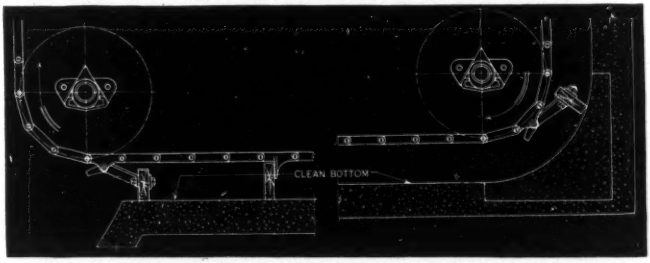


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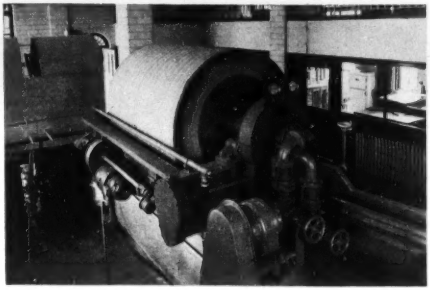

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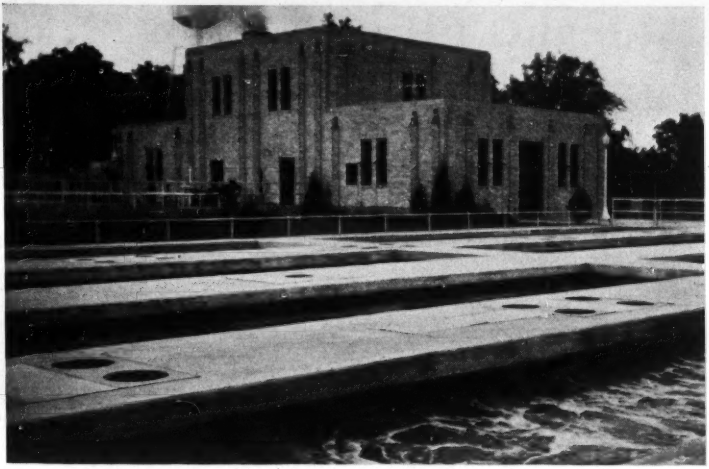

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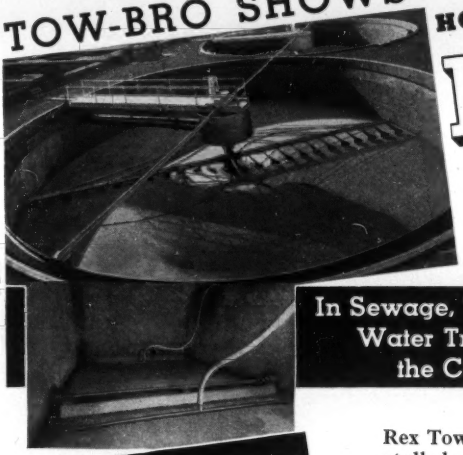

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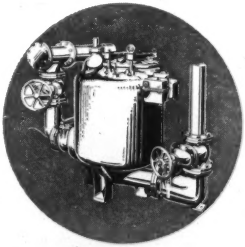

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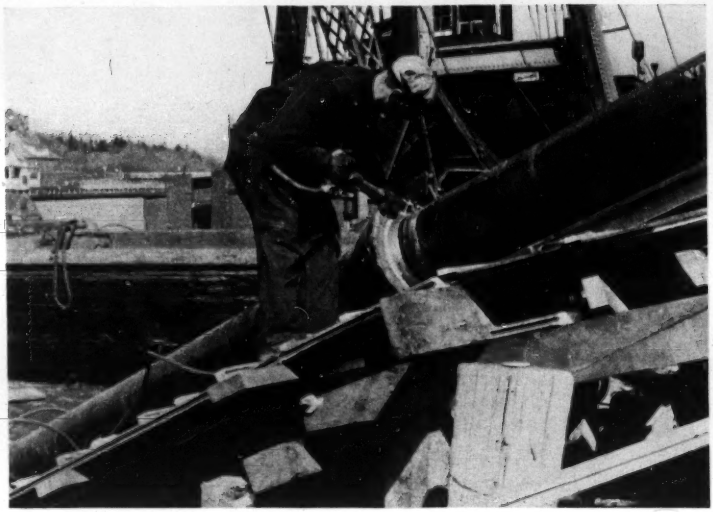

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Vol. IX September, 1937 No. 5

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# Sewage Research

## STUDIES ON THE CLARIFICATION OF ACTIVATED SLUDGE.* III. CARBON DIOXIDE PRODUCTION DURING THE CLARIFICATION AND OXIDATION STAGES OF ACTIVATED SLUDGE

By H. Heukelekian and R. S. Ingols

*Associate and Assistant, Div. Water and Sewage Research, New Brunswick, N. J.*

The ultimate removal of organic impurities of sewage by activated sludge and the restoration of the activity of the sludge is admittedly dependent on oxidation. A number of studies have been conducted to measure the oxygen consumption of sludge and mixtures of sludge and sewage.

Carbon dioxide is the main end product of aerobic decomposition, as methane and carbon dioxide are the main products of decomposition under anaerobic conditions. The information gained by gas measurements in the anaerobic digestion of sludge has been invaluable for the study of the nature and course of digestion, so the measurement of $CO_2$ production under aerobic conditions should aid in interpretation and throw some light on the process. Since in practice the cycle in the activated sludge process is completed in 6 to 8 hours, the time intervals for the measurement of $CO_2$ production have to be shorter than the day intervals used for the measurement of the digestion gases. It was hoped by such a procedure (1) to reproduce the type curve of oxidation of activiated sludge mixtures, (2) to indicate any variations from the type curve due to variations of experimental conditions, (3) to determine the change in the rate of oxidation within the normal period of aeration, and (4) to determine when the cycle was complete.

It should be stated at the outset that the $CO_2$ production values can not be converted directly to oxygen consumption values because the respiratory quotient ($CO_2/O_2$) is not constant.[4, 10] In spite of this the information obtained by this technique can be interpreted as reflecting the course of oxidation and throw some light on the specific questions raised above.

### Methods

Samples of activated sludge and sewage were obtained from different plants. Aeration and $CO_2$ measurements were started within a few hours after the samples were taken. In order to eliminate the $CO_2$ accumulated in the sludge during the period of transportation and preparation and before preparing the mixtures for experimental use, the returned sludge was preaerated for a sufficiently long period to bring the

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Division Water and Sewage Research.

$CO_2$ production to a stationary low level. This usually required 30 minutes. The $CO_2$ acidity of the sewage was measured by titration with and without boiling the sample. The $CO_2$ measured in this way represented only a very small fraction of the $CO_2$ produced from the mixtures during the first 10 or 20 minutes of aeration and has therefore been diregarded. The sludge concentration in the mixtures were adjusted to 2000 p.p.m. suspended solids. Carbon dioxide measurements were made according to the method described elsewhere.[4] Known volumes of 0.1 normal $Ba(OH)_2$ solution were placed in 10-bulb absorption tubes and these were connected to the aeration tubes. The $CO_2$ evolved was measured at the desired intervals by replacing the absorption tube with another one filled with a like volume of the standard barium hydroxide. The excess $Ba(OH)_2$ was back titrated with oxalic acid.

## Results

The rates of $CO_2$ production in three typical runs with different returned sludge and sewage mixtures are given in Figs. 1, 2 and 3. The B.O.D. of the sewages as well as the total amount of $CO_2$ produced from these mixtures are given in Table I. The two sewages employed in

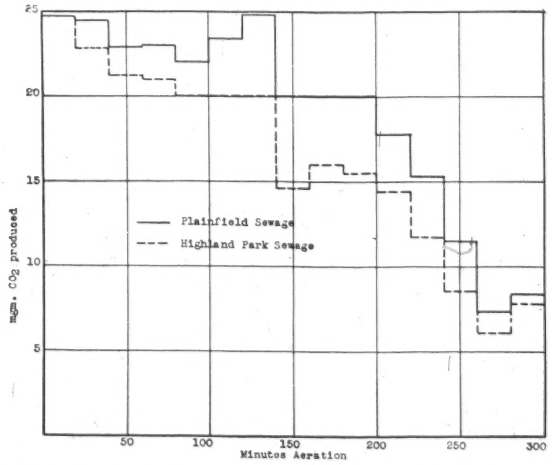


FIG. 1.—Rate of $CO_2$ production from activated sludge mixtures made with sewage from Plainfield (B.O.D. 320 p.p.m.) and sewage from Highland Park (B.O.D. 340 p.p.m.).

the first experiment (Plainfield and Highland Park) had B.O.D. values which were nearly alike (320 and 340 p.p.m. respectively) but when these were mixed with the same returned sludge (Madison-Chatham) and aearated, significantly different rates and amounts of $CO_2$ were produced. The $CO_2$ production from the mixture made with Highland

Park sewage dropped during the first hour, remained constant during next hour, took a sudden drop after 140 minutes of aeration, remained constant again up to 220 minutes of aeration and dropped thereafter

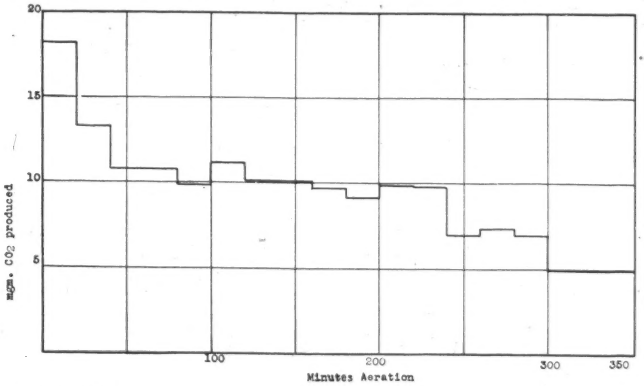


FIG. 2.—Rate of $CO_2$ production from activated sludge mixture made with sewage from Highland Park (B.O.D. 85 p.p.m.).

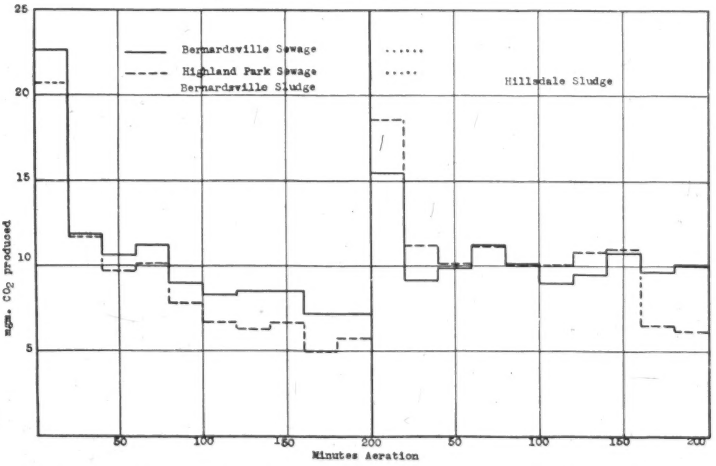


FIG. 3.—Comparison of rate of $CO_2$ production from 4 mixtures made with two returned sludges and two sewages.

up to 280 minutes of aeration. The $CO_2$ production from the mixture made with the Plainfield sewage dropped only slightly during the first 100 minutes of aeration and then indicated a small but definite increase, thereafter the decrease paralleled that of the mixture made with the

Highland Park sewage. In both mixtures a low level of $CO_2$ production was attained within 260 to 300 minutes. The total $CO_2$ production (per liter of mixture of 800 c.c. sewage and 200 c.c. returned sludge) was 292 mgm. from the mixture made with Plainfield sewage and 250 mgm. with the mixture made with Highland Park sewage.

TABLE I.—*The B.O.D. Values of the Different Sewages and the Total $CO_2$ Production from the Mixtures Made from Them*

| Fig. | Sludge From | Sewage From | Aeration Period Minutes | B.O.D. of Sewage P.p.m. | Total $CO_2$ Produced, Mgm. |
|---|---|---|---|---|---|
| 1 | Madison | Plainfield | 320 | 320 | 292 |
| 1 | " | Highland Park | 320 | 340 | 250 |
| 2 | " | " " | 320 | 85 | 159 |
| 3 | Bernardsville | Bernardsville | 200 | 185 | 112 |
| 3 | " | Highland Park | 200 | 120 | 96 |
| 3 | Hillsdale | Bernardsville | 200 | 185 | 115 |
| 3 | " | Highland Park | 200 | 120 | 110 |

It appears that the B.O.D. of the sewage gives only a rough indication of the amount of $CO_2$ to be expected from it when aerated in the presence of activated sludge and therefore the B.O.D. gives only an approximate picture of the load. The discrepancy between the $CO_2$ and B.O.D. values is not surprising when the great differences in the conditions of B.O.D. and $CO_2$ determinations are borne in mind. The first measures the amount of oxygen consumed in the oxidation of organic matter in a quiescent state in the presence of sewage organisms only. The latter measure the $CO_2$ production as a result of oxidation of organic matter in the presence of the highly specialized organisms in activated sludge with constant agitation. It may well be that certain organic materials may not be oxidized even during the 5-day incubation period of the B.O.D. determination, while they may readily be oxidized in the few hours of aeration in the presence of sludge. The better method of determining the existing or the optimum load on a plant may be to express it on the basis of $CO_2$ production when aerating the sewage in the presence of activated sludge.

The $CO_2$ production from an activated sludge mixture made with a weak sewage (B.O.D. 85 p.p.m.) is represented in Fig. 2. After the first 40 minutes of aeration a low level was maintained for a period of 240 minutes and thereafter a further decrease took place. The rate of $CO_2$ production was lower than when sewages with higher B.O.D. were employed. The total amount of $CO_2$ produced from a liter of the mixture (800 c.c. of sewage and 200 c.c. of sludge) in 320 minutes of aeration was 159 mgm. Thus within certain wide limits the B.O.D. of the sewage and the $CO_2$ produced on aerating it with activated sludge correspond. The type of the curve can be considered the same as those in Fig. 1, with the period of maximum $CO_2$ production reduced to 40 minutes.

A further study of $CO_2$ production from four sludge mixtures made with Bernardsville and Highland Park sewages and Bernardsville and Hillsdale sludges is given in Fig. 3. The B.O.D. of the Bernardsville sewage was 185 p.p.m. and that of Highland Park 120 p.p.m. The most rapid $CO_2$ production took place during the first 20-minute period of aeration in all the mixtures and there were no secondary increases in the rate of $CO_2$ production. The curves are similar to that obtained from the mixture made with a sewage of 85 p.p.m. B.O.D. in so far as there is no protracted period of maximum $CO_2$ production. The total $CO_2$ production with the slightly stronger Bernardsville sewage was somewhat higher than with the Highland Park sewage in the mixture made with the Bernardsville sludge, while there was no difference with the same sewages mixed with Hillsdale sludge. It seems again that the B.O.D. of the sewage is not the only factor in determining the amount of $CO_2$ production and of the oxidizability of sewage when aerated in the presence of activated sludge.

There are obviously two factors involved in the determination of the oxidizable matter in sewage by any method, *e.g.* the total amount and the type and character of the material.

In the previous experiments with different sewages both of these factors were variable. By concentrating or diluting a given sewage the chemical character can be kept constant changing only the concentration. Carbon dioxide measurements by aerating a mixture in which the concentration of sewage has thus been artificially changed should determine whether the time necessary for aeration and total amount of $CO_2$ produced is proportional to the concentration of sewage.

A portion of sewage from Highland Park was accordingly diluted to twice its volume with water and another portion concentrated by vacuum distillation to 2.5 times its original strength. Mixtures of these sewages were made with returned sludge from Madison which had been previously aerated for 15 minutes. The amount of sludge was the same in each mixture (20 per cent by volume and 2000 p.p.m. suspended solids concentration). Carbon dioxide was measured from the aerating mixtures at half hourly intervals for a period of 9 hours. The results are shown in Fig. 4 and Table II. The $CO_2$ production in the mixture with half the normal strength of sewage reached a low level within 1½

TABLE II.—*Effect of the Strength of Sewage in Activated Sludge Mixtures on the Time and Total $CO_2$ Production*

| | Half Strength | Normal Strength | 2.5 ×Normal Strength |
|---|---|---|---|
| Time required for the initial period, hrs. | 1½ | 3 | 7 |
| $CO_2$ produced during the initial period, mgm. | 45.5 | 112 | 282 |
| Time required for the initial and secondary periods, hrs. | 2½ | 4 | 7 |
| $CO_2$ produced during the initial and secondary periods, mgm. | 72.5 | 142 | 282 |
| $CO_2$ produced in 7 hours, mgm. | 190 | 231 | 282 |

hours of aeration and remained more or less constant thereafter. Within this initial period it produced 45.5 mgm. $CO_2$. The mixture with the original sewage reached a low level of $CO_2$ production after 3 hours aeration and remained at a constant level which was higher than the level of the mixture with the half-normal strength sewage. A total of 112 mgm. of $CO_2$ was produced during the 3 hour aeration period from this mixture. The mixture with the concentrated sewage required a 7 hour aeration period before a low level was attained and it produced 282 mgm. of $CO_2$ within this period. There seems to be a direct relation between the strength of sewage and the time required to reach a low level of $CO_2$ production as well as the amount of $CO_2$ produced within that period.

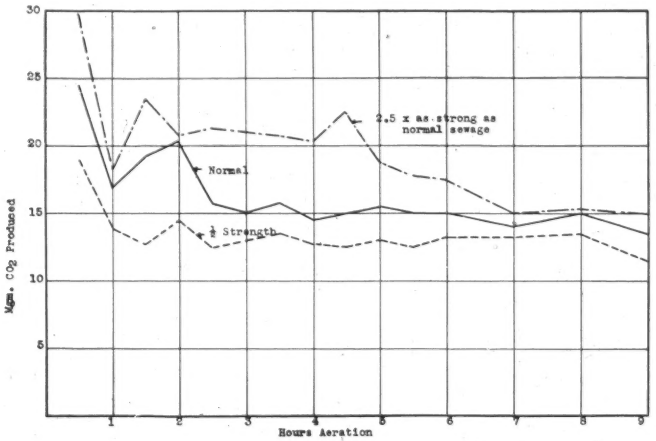


FIG. 4.—Effect of varying sewage strength upon $CO_2$ production from mixtures of activated sludge.

The selection of the time for the low level of $CO_2$ production was arbitrarily set as the first low point and not the low point after the small secondary rise. By changing the criterion to include the secondary rise the values for the minimum time for $CO_2$ production would be changed for the mixture with half the normal strength of sewage from 1½ hours to 2½ hours and for normal strength sewage mixture from 3 to 4 hours. The values obtained on this basis will still show a definite relation between concentration of sewage and time, although it is no longer the straight line relationship. It should also be mentioned in justification of the estimation of total $CO_2$ produced on the basis of the time for the low level to be attained, that $CO_2$ production thereafter is predominantly from the sludge and does not represent the oxidation of the sewage. The amount of $CO_2$ produced from the sludge itself during the early period of aeration would be comparatively small.

## Discussion

The results presented give a clear picture of the rate of $CO_2$ production and oxidation obtained when sewage and activated sludge are aerated. The normal type of curve obtained is one that gives the maximum $CO_2$ production in the initial period of aeration. Under abnormal conditions the type curves changes, as is illustrated in Fig. 5. No B.O.D. figures are available for this sewage which was from Highland Park but it was a very strong sewage as indicated by its turbidity and odor. After the initial 20 minutes, the $CO_2$ production dropped to a low level and remained low up to 80 minutes of aeration. Thereafter it increased up to 160 minutes. A decrease took place during the next

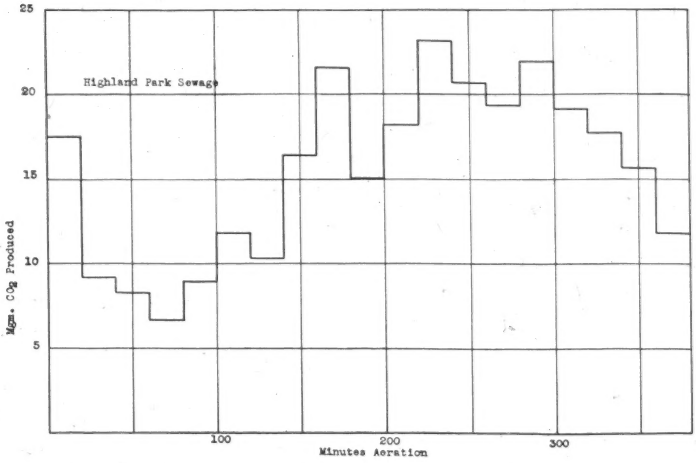


Fig. 5.—Atypical or abnormal rate of $CO_2$ production from a sludge sewage mixture.

20 minute period, followed by another increase. The $CO_2$ production began to fall off finally only after 300 minutes of aeration and after 380 minutes the rate was 12 mgm. per 20 minutes which was double the rate attained after 320 minutes in the previous mixtures. A total of 294 mgm. of $CO_2$ was obtained from a liter of the mixture (800 c.c. sewage and 200 c.c. sludge) in 380 minutes.

The second rise in the curve would indicate some kind of a retarding influence, for the total amount of $CO_2$ produced was not materially higher than that produced from moderately strong sewages, which did not show signs of retardation in $CO_2$ production. The retarding influence might have been caused by the presence of some toxic material in the sewage or by the nature of the sludge. In this case, the sewage employed was of strictly domestic origin, and industrial wastes can not be held responsible for the abnormality. The presence of septic ma-

terial may play a role. The lack of an oxidizing flora in the sludge and over-oxidation of the sludge might also be mentioned as factors. Departure from the $CO_2$ type curve and the causes will be discussed in a future paper.

In normal respiration the duration of the initial high rate of $CO_2$ production seems to be dependent on the initial strength of the sewage. With a weak sewage the high rate of $CO_2$ production is over within 20 to 40 minutes, while with stronger sewages 4 to 5 hours are required before a low level is reached. This raises the interesting question as to whether the time necessary for the aeration of a given sewage can be determined from the $CO_2$ production results and if so at what stage of the $CO_2$ production curve can the sewage be considered as satisfactorily oxidized and the sludge reconditioned. Is it just after the initial period of high rate of $CO_2$ production or is a further period of aeration necessary?

The application of the findings to the theory of the mechanism of clarification is important.

Theriault and McNamee [8] were led to believe that the initial purification of sewage by activated sludge was of chemical or enzymatic nature because (1) the velocity constants for this stage of purification approached that of the order of chemical reactions and (2) the deoxygenation constants for river water B.O.D. were of much lower order. Although enzymatic reactions were mentioned, the impression is created that they were not considered to be of biochemical nature. However, biochemical enzymatic reactions can respond to stimulation and evolve great amounts of energy.

In Fig. 1, two grams of a sludge-sewage mixture produced 70 mgm. $CO_2$ per hour.

On a Kg. basis, .070 gm. $CO_2 \times 500 = 35$ gm. $CO_2$/hr. From the relation given by the equation:

$$6O_2 \pm C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 674 \text{ Kg. Cal.}$$

$$264 \text{ gm. } CO_2 + 674 \text{ Kg. Cal.}$$

$$\frac{35}{264} \times 674 = 89.4 \text{ Kg. Cal./hr./Kg. (dry wt.).}$$

The use of the oxidation of glucose as the criterion of the energy liberated by the activated sludge in relation to the $CO_2$ produced is purely arbitrary. However, the amount of energy liberated from glucose is quite representative of the amount of energy which might be liberated by the materials generally found in sewage.

The results obtained by us and by other workers on the rate of oxidation of activated sludge mixtures confirm the *a priori* reasoning that activated sludge possesses the potentiality and mechanism of rapid oxidation. The literature on the rate of oxidation of activated sludge has been reviewed by others [7] extensively and the reason for again critically reviewing is for the purpose of re-interpreting the existing evidence. None of the previous investigators drew the obvious conclusion that during the so-called clarification stage, maximum oxidation

was also taking place, although the results pointed in that direction. The reason for this might be the difficulty of interpreting the oxygen consumption figures on the basis of biochemical reactions. There has always been the ever-present possibility of the high rate of oxygen consumption being due to direct chemical oxidation.

Grant, Hurwitz and Mohlman [3] have presented figures which show that the rate of oxygen absorption in activated sludge plus sewage mixtures is highest for the first unit of time. The curves tend to attain a straight line relation with increasing time of aeration especially with the higher concentration of sludge in the mixture. Their point of emphasis was on the effect of different sludge concentrations in the mixture on the rate and absolute amount of oxygen absorption from the standpoint of supplying the demand by adequate aeration. They have shown that oxygen absorbed by the sewage component of activated sludge mixture was greater in the presence of lower concentrations of sludge than in the presence of higher concentration.

Theriault and McNamee's [8] studies show that even sludge to which no sewage has been added when reaerated, takes up oxygen faster during the first hour than in subsequent hours.

Kessler and Nichols [5] expressed the results of oxygen consumption, by weight, per million parts per hour of liquid sludge, as the Nordell number. For activated sludge-sewage mixtures the Nordell number was highest during the initial period and decreased regularly after a more or less constant initial values.

Wooldridge and Standfast [10] using the Barcroft differential manometer showed that oxygen adsorption by activated sludge-sewage mixtures was greatest during the first hour. The same thing was true with sewage and sludge samples aerated separately.

Goldthorpe's [2] results show similarly that the rate of oxygen absorption by activated sludge sewage mixtures is greatest for the first 30 minutes and decreases regularly thereafter.

McNamee's [6] results show that the rate of oxygen absorption by activated sludge mixtures is greatest during the first hour and decreases regularly thereafter up to 6 or 8 hours aeration. Further aeration up to 20 to 24 hours gives absorption results which fall in a straight line, similar to the adsorption rate of the sludge component aerated separately. The oxygen absorption calculated from the difference between the mixture and the sludge show similarly decreasing rates with increasing periods of aeration up to 5 to 8 hours. Thereafter the rate of absorption becomes stationary.

Butterfield, Ruchhoft and McNamee [1] later obtained results which also show a high rate of oxygen uptake during the initial periods, by aerating the special sludge produced from pure cultures of Butterfield's zooglea organism in sterilized natural or synthetic sewage.

Thus there has accumulated sufficient evidence, from the standpoint of oxygen absorption by activated sludge-sewage mixtures, to indicate that the highest rate occurs during the earliest periods of aeration, whether a 10, 20, 30 or 60 minute period is selected as the unit of time.

Thereafter for every equal unit of time the rate of oxygen absorption decreases. These initial high rates of oxygen absorption have not been used as supporting evidence of the importance of biochemical oxidation during the clarification stage but the possibility that these observed high rates might be due to chemical reaction of oxygen with some reducing substances in sewage has been emphasized. Undoubtedly reducing substances exist in sewage, especially as the sewage becomes stale. But Wooldridge and Standfast [9] have shown that sterile sewage (autoclaved or Seitz filtered) does not absorb any oxygen. A small part of the initial high rate of oxygen absorption might also be attributed to the building up of dissolved oxygen in the mixture during this period. However carbon dioxide production must be attributed solely to biochemical oxidation. It is true that the respiratory quotients as reported by Wooldridge and Standfast [10] and Heukelekian [4] are lower than normal for biochemical oxidation of fats, carbohydrates and proteins. This might be attributed to high oxygen consumption values or to low $CO_2$ production values of the activated sludge mixtures. The respiratory quotient increases with the period of aeration [10] indicating that there might be a lag period after the oxygen is consumed before $CO_2$ is produced. The respiratory quotient might also increase on account of the apparent lower rate of consumption after the dissolved oxygen tension in the liquid is built up.

The evidence from theoretical considerations as well as experimental evidence indicates that the oxidative mechanism of activated sludge is ample to account for the initial rapid rate of purification. Clarification implies the removal of the organic and inorganic particulate matter that causes turbidity.

The removal of inorganic matter can not be attributed to biochemical reaction. The oxidative mechanism can not be directly responsible for the removal of organic matter. Intervening stages of hydrolysis of this matter are essential before the organisms can utilize it as a source of energy. Following hydrolysis there will be a consumption of oxygen and production of carbon dioxide. Most of the initial high rate of oxidation is to be attributed to the soluble materials initially present in sewage. However in subsequent papers it will be shown that sludge has an adequate mechanism for hydrolysis. This provides the necessary food for the oxidation mechanism. It should be clear from the foregoing discussion that division of the process of purification by activated sludge into (1) primarily clarification and (2) primarily oxidation stages is not warranted. The processes of clarification and oxidation proceed simultaneously and the highest rate of clarification coincides with the period of highest oxidation rate. The stimulus needed for the different mechanisms is the addition of new food in the form of sewage.

## Summary and Conclusions

Results obtained by measuring $CO_2$ production over short intervals of time during the aeration of activated sludge and sewage mixtures

show that generally the highest rate occurs during the initial period. The duration of the high rate of $CO_2$ production is dependent on the strength of the sewage. It is indicated that $CO_2$ production from mixtures might be a more reliable way of determining the load on the aeration tank than B.O.D., because $CO_2$ measurements are made under conditions more comparable to the aeration tanks than B.O.D. measurements. The method is simple and inexpensive in contrast to other existing methods, which might be used for the same purpose such as the Barcroft differential manometer and the Nordell machine.

The theoretical aspect of the findings emphasizes the importance of oxidation during the clarification stage and points out that biochemical oxidation systems in the activated sludge have the potentiality, with proper stimulation in the presence of food and air, to react rapidly without any lag.

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# HIGH AND LOW TEMPERATURE DIGESTION EXPERIMENTS.* IV. EFFECT OF CERTAIN TOXIC WASTES

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Of the many toxic wastes received either continuously or intermittently at sewage plants, certain wastes are of more importance than others. For a study to determine the effect of such wastes on the digestion of sewage solids, gas and odor production and possible operation difficulties, both under mesophilic and thermophilic conditions, representative materials were selected. The results reported in this paper are restricted to copper sulphate, sodium arsenate, gasoline, sulphuric acid and waste crank case oil.

## *A.* Effect on Mesophilic Digestion

*Materials, Methods, Procedure.*—The fresh solids and ripe sludges were collected from different sewage treatment plants in New Jersey. The poisons, oil and gasoline were mixed in different quantities with the fresh solids and added to the ripe sludge. The ripe sludge produced from these mixtures was then used for seeding and the process repeated to determine possible acclimatization. Gasoline was bought at a distribution station and the waste crank case oil was taken from an automombile when a change of oil was made. For several years an effort has been made in New Jersey to collect waste oil for mosquito control. Some years as much as 300,000 gallons have been used for this purpose. A portion of the oil is collected for straining and filtering, but an appreciable amount is discharged into the sewers.

Analyses were made of the fresh solids and ripe sludges used and solids, ash, and pH determinations made of the mixtures at intervals. Gas was collected and measured daily, with occasional analyses to determine the composition of the gas. Before the gases were passed into the gasometers, hydrogen sulphide was determined as previously described (1). Results of the analyses of the sludges used, together with other pertinent data, are shown in the appropriate tables.

### Results

*Copper Sulphate.* The quantities of copper sulphate added varied from 0.01 to 0.2 per cent on the basis of the volatile matter in the fresh solids. Only those results are reported that show the essential facts necessary for interpretation. The quantities of copper sulphate per liter of fresh solids and on the basis of sewage containing 200 p.p.m. suspended solids used for illustration were as follows:

* Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Div. Water and Sewage Research.

| Fresh Solids Grms./liter | Per Cent of Dry Vol. Mat. of Sludge | Computed to Sewage P.p.m. |
|---|---|---|
| 7.60 | 0.037 | 8 |
| 15.25 | 0.075 | 16 |
| 30.50 | 0.112 | 32 |

Some results obtained are shown in Table I, while the cumulative gas production per gram of volatile matter is shown in Fig. 1. Gas pro-

TABLE I.—*Effect of Copper Sulphate and Sodium Arsenate on Volatile Matter Reduction and Gas Production*

| Added on Basis of V. M. in Fresh Solids Per Cent | Vol. Matter, Begin. Per Cent | Vol. Mat. Red. After 10 Days Per Cent. | Vol. Mat. Red. After 30 Days Per Cent | Gas/Grm. V. M. Added After 30 Days C.C. | V. M. Red. After 60 Days Per Cent | Gas/Grm. V. M. After 60 Days C.C. | $H_2S$ Prod. as S Mgr. | pH. Begin. | pH. End |
|---|---|---|---|---|---|---|---|---|---|
| Controls | 3.25 | 15.5 | 34.6 | 460 | 34.5 | 650 | 0.41 | 6.8 | 7.8 |
| $CuSO_4$ 0.37 | 2.78 | 7.2 | 27.7 | 526 | 38.8 | 584 | 2.50 | 6.8 | 8.0 |
| 0.75 | 2.78 | 8.6 | 29.3 | 56 | 37.8 | 56 | 1.05 | 6.8 | 7.4 |
| 0.112 | 2.78 | 2.1 | 14.2 | 2 | 20.1 | 2 | 0.04 | 6.8 | 6.8 |
| $Na_3AsO_4$ 0.018 | 2.84 | 12.1 | 29.7 | 381 | 38.4 | 590 | 1.24 | 6.8 | 7.7 |
| 0.037 | 2.80 | 1.5 | 7.5 | 132 | 18.4 | 181 | 0.75 | 6.8 | 7.6 |
| 0.075 | 2.78 | 0.0 | 5.5 | 86 | 10.4 | 91 | 0.72 | 6.8 | 7.3 |

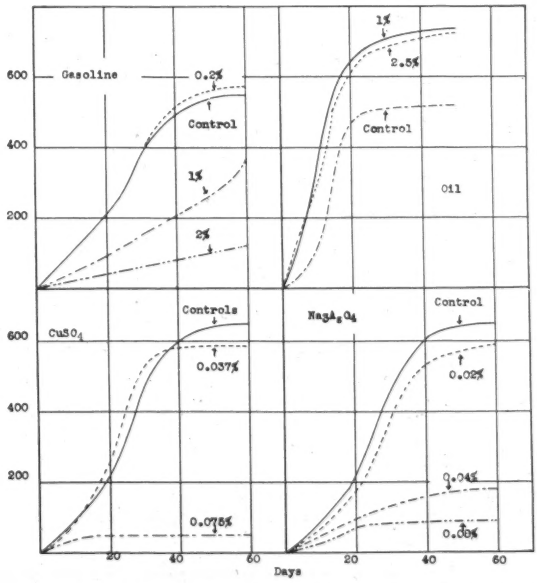


FIG. 1.—Cumulative gas production from mixtures with different wastes.

duction was not affected by quantities of copper sulphate less than 0.03 per cent on the basis of the volatile matter in the fresh solids, and only slightly affected with additions of 0.04 per cent or in a concentration of 0.025 per cent of the total mixture. During the first part of the digestion period gas production was actually somewhat stimulated. Larger additions progressively retarded volatile matter reduction and gas production. Quantities of 0.075 per cent copper sulphate suppressed nearly all gas production, while volatile matter reduction was only slightly retarded. With still greater amounts of copper sulphate no gas was produced but volatile matter reduction was still evident. The copper sulphate in smaller quantities (up to 0.75 per cent) appeared to interfere only slightly with liquefaction, but gasification was greatly retarded with amounts above 0.5 per cent. It seems that either copper sulphate had a selective action on the gas-forming organisms or that these organisms are more susceptible to this poison than the large group of liquefiers.

*Sodium Arsenate.*—Sodium arsenate was added to fresh solids in quantities varying from 1 to 16 p.p.m. on the basis of sewage of average strength, assuming that this poison would be present in the fresh settled solids. The mixtures of most interest contained the following amounts of sodium arsenate:

| Fresh Solids Grms./liter | Per Cent of Dry Vol. Mat. of Sludge | Computed to Sewage P.p.m. |
|---|---|---|
| 2.0 | 0.018 | 2 |
| 3.90 | 0.037 | 4 |
| 7.80 | 0.075 | 8 |

Some condensed results obtained are shown in Table 1 and a comparison of the cumulative gas produced per gram of volatile matter is shown in Fig. 1. Even the small quantity of 2 p.p.m. sodium arsenate caused some retardation in gas production, but with larger quantities digestion and gas production were greatly retarded. With 4 p.p.m. added digestion after 60 days was equal only to the control after about 12 days. This was true both for gas production and volatile matter reduction.

After a digestion period of 150 days these mixtures had not produced as much gas as the controls in 30 days, indicating that the toxic action of the sodium arsenate was rather persistent.

*Gasoline.*—The additions of gasoline on the basis of the volatile matter in the fresh solids varied from 0.5 to 10 c.c. per liter of sludge mixture or from 1 to 20 c.c. per liter of fresh solids. Gasoline appears to attach itself readily to the solid particles and is carried down into the sludge. Some of the more pertinent results are shown in condensed form in Table II, and gas production for the first 60 days of digestion is shown in Fig. 1. The curves show that there was no effect on gas production when 0.2 per cent by volume (on the basis of fresh solids) was added, but 1 per cent gasoline had a strongly retarding effect. After 150 days digestion the mixture with 1 per cent gasoline had not

produced as much gas as the control in 60 days and the mixture with 2 per cent gasoline had not produced as much gas after 150 days as the control in 30 days. In addition to retardation of gas production the per centage reduction of volatile matter was decreased. With 1 per cent gasoline, volatile matter reduction after 150 days amounted to only 26.6 as compared with 34.6 per cent after 30 days digestion of the control.

TABLE II.—*Effect of Gasoline on Digestion*

| Gasoline Added on Basis of Vol. Matter in Fresh Sol. Per Cent | Vol. Matter, Begin. Per Cent | V. M. Red. After 10 Days Per Cent | V. M. Red. After 30 Days Per Cent | Gas/Grm. V. M. Added, (After 30 Days) C.C. | V. M. Red. After 60 Days Per Cent | Gas/Grm. Vol. M. After 60 Days C.C. | $H_2S$ Prod., as S Mgr. | pH, Begin | pH, End |
|---|---|---|---|---|---|---|---|---|---|
| none | 3.35 | 15.4 | 34.4 | 461 | 34.7 | 656 | 0.40 | 6.8 | 7.7 |
| 0.19 | 2.84 | 14.0 | 30.8 | 453 | 34.1 | 670 | 1.84 | 6.8 | 8.0 |
| 0.94 | 2.75 | 4.3 | 8.2 | 153 | 18.2 | 364 | 1.05 | 6.8 | 8.0 |
| 1.89 | 2.82 | 2.1 | 8.5 | 62 | 20.0 | 123 | 1.28 | 6.8 | 7.4 |

*Crank Case Oil.*—Waste oil is discharged and received at sewage plants almost continuously, but occasionally large quantities enter for short periods. For these reasons the quantities of oil employed in the experiments covered a rather wide range, namely from 10 to 250 grams per liter of sludge. Analyses of the materials used showed that the ripe sludge had 4.76 per cent solids with 48.8 per cent ash, the fresh solids had 4.58 per cent solids and 21.6 per cent ash, while the oil contained 0.6 per cent fixed material. The mixtures were incubated at 80° to 82° F. In addition to gas collection, solids, ash, total fats and

TABLE III.—*Effect of Oil on Digestion*

| Oil Added per Liter Fresh Solids Gms. | At Beginning | | | | After 35 Days | | | |
|---|---|---|---|---|---|---|---|---|
| | Total Solids Per Cent | Ash Per Cent | Total Fats and Soap Per Cent | pH | Vol. Matter Red. Per Cent | Total Fats, Red. Per Cent | Gas/Grm. Fresh Sol. Added C.C. | pH |
| 0 | 4.77 | 35.7 | 18.4 | 7.4 | 33.9 | 61.5 | 518 | 7.8 |
| 10 | 5.06 | 32.6 | 35.2 | 7.4 | 14.6 | 29.2 | 727 | 7.8 |
| 25 | 6.51 | 26.4 | 48.3 | 7.4 | 8.8 | 15.0 | 710 | 7.8 |

oils were determined at the begining and end of the experiment. To facilitate sampling for fat and oil extraction, known quantities of infusorial earth were added to the dried samples. From the standpoint of regular additions of waste oil the results obtained on mixtures up to 25 grams oil per liter of sludge are of greatest interest. Some of the results obtained after a period of digestion for 35 days are shown in Table III. The cumulative gas production per gram of fresh solids

added (oil not taken into consideration) for a period of 50 days is shown in Fig. 1. The quantities of waste oil added were assumed to be equivalent to 40 and 100 gallons per million gallons of sewage of average strength and it was also assumed that all oil would be carried down into the sludge. Based on the volume of fresh sludge, the quantity of oil added would be equivalent to 1 and 2.5 per cent. The results indicate that the addition of waste oil in these quantities had no detrimental effect on gas production. More gas was produced per gram of fresh solids when oil was present, but volatile matter destruction decreased. Total volatile matter destruction per liter of fresh solids was, for the control 15.8 gms., with 1 per cent oil 10.8, and with 2.5 per cent oil 9.8 gms. It seemed therefore that the mineral oil was responsible for the gas. In this respect it is of interest to know that the composition of the gases produced during the digestion period was rather constant. This is illustrated in Table IV, where the composition of

TABLE IV.—*Composition of Gas after 10 and 17 Days Digestion*
All Results in Per Cent by Volume

| Oil Added | After 10 Days | | | | After 17 Days | | | |
|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | $O_2$ | Combustible | Inert | $CO_2$ | $O_2$ | Combustible | Inert |
| None | 18.6 | 0.1 | 74.5 | 6.8 | 15.1 | 0.2 | 82.2 | 2.5 |
| 10 c.c. | 17.6 | 0.2 | 77.6 | 4.6 | 15.2 | 0.1 | 78.7 | 6.0 |
| 25 c.c. | 18.6 | 0.0 | 80.4 | 1.0 | 15.7 | 0.2 | 81.8 | 2.3 |

the gas before and at the approximate peak of gas production is shown.

*Sulphuric Acid.*—Certain industrial wastes contain considerable quantities of sulphuric acid or larger quantities of sulphates in an acid medium. Such waste may conceivably affect the rate of digestion as well as stimulating odor production. Quantities of sulphuric acid varying from 0.25 to 1 per cent on a volume basis were added to fresh solids—ripe sludge mixtures. Some of the results obtained are shown in Table V. The addition of sulphuric acid affected the initial reaction of the mixtures materially, but at the end of 35 days all mixtures, except the one receiving the highest quantity, were slightly above the neutral

TABLE V.—*Effect of Sulphuric Acid on Digestion (35 Days)*

| $H_2SO_4$ Added Per Cent | Solids, Begin. Per Cent | Ash, Begin. Per Cent | pH, Begin. | pH, End | Solids Reduction Per Cent | Gas/grm. Fresh Sol. C.C. | $H_2S$ Prod. P.p.m. |
|---|---|---|---|---|---|---|---|
| 0 | 5.52 | 31.7 | 6.9 | 7.4 | 38.7 | 593 | 41 |
| 0.25 | 5.30 | 30.8 | 6.5 | 7.5 | 41.8 | 672 | 265 |
| 0.50 | 5.30 | 33.9 | 6.3 | 7.5 | 36.6 | 12 | 378 |
| 0.75 | 5.06 | 32.5 | 5.9 | 7.1 | 32.5 | 0 | 417 |
| 1.00 | 5.76 | 30.9 | 5.3 | 5.3 | 43.7 | 0 | 211 |

point. The percentage solids reduction was in all instances about the same as would be expected from well digested mixtures. Total gas production from the mixtures receiving more than 0.25 $H_2SO_4$ was practically nil, but these mixtures produced considerably more hydrogen sulphide than the control. The mixture to which 0.25 per cent $H_2SO_4$ was added produced somewhat more gas in 35 days, but the time required to reach the peak of gas production was increased by 30 per cent. Gasification of the control was practically completed in 23 days but the time required for the mixture with the acid was increased to 35 days. At the time when 90 per cent of the gas was produced from the control, only about 38 per cent of the total gas had been evolved from the mixture with acid.

In a number of instances it has been observed that certain trade wastes reduce gas production materially and sometimes they prevent gas production entirely. Such results have been obtained with milk waste, certain wool wastes, acid iron waste and others. It does not seem that the reaction of the medium, in the case under discussion, was the only or the controlling factor throughout the duration of digestion, because the mixture with 0.25 per cent $H_2SO_4$, having an initial pH of 6.5 and finally 7.5, produced abundant gas whereas the mixture receiving 0.5 per cent $H_2SO_4$, with an initial pH of 6.3 and finally 7.5, produced very little gas. It appears that acidic substances, either mineral or organic, affect the gas-forming and especially the methane-producing organisms. On the other hand, hydrolysis of the organic material is not impaired and liquefaction may even be stimulated by acidic or acid-producing substances.

With the increase in total sulphur, the quantities of $H_2S$ produced increased, but not in proportion to the amounts of sulphate added. This is illustrated in Table VI, where the quantities of sulphur present

TABLE VI.—*Hydrogen Sulphide Production*

| $H_2SO_4$ Added P.p.m. | Total Sulphur Present Mgr. | $H_2S$ Mgr. | S Changed to $H_2S$ Per Cent |
|---|---|---|---|
| 0 | 12.2 | 2.7 | 22 |
| 250 | 14.7 | 10.0 | 68 |
| 500 | 17.5 | 14.2 | 81 |
| 750 | 24.2 | 16.5 | 68 |
| 1000 | 31.0 | 7.3 | 22 |

in the solids and the amounts added are compared with the $H_2S$ produced per gram of dry solids. The mixture receiving the largest quantity of $H_2SO_4$ produced apparently less $H_2S$, but this is due to the fact that not all $H_2S$ which could be produced had evolved at the termination of the experiment.

## ACCLIMATIZATION

The method of acclimating sludge to the wastes has been described in more detail (1) and consisted briefly of using sludge produced in

previous experiments, treating it again with the same waste in increasing quantities. Some mixtures used for discussion, together with some of the results obtained for different poisons are shown in condensed form in Table VII.

TABLE VII.—*Seed Used, Total Gas, Volatile Matter Reduction and $H_2S$ Production With Poisons Added*

| Waste Added | Waste in Mix. Per Cent | Seed From Mixtures With | Gas After, Days | | | Volatile Matter Red. Per Cent | $H_2S$ as S Mgm. | $H_2S$ in Gas Per Cent | Ratio Waste : Fresh Sol. : Ripe Sludge |
|---|---|---|---|---|---|---|---|---|---|
| | | | 20 C.c. | 39 C.c. | 87 C.c. | | | | |
| None..... | 0 | Plainfield | 536 | 670 | 760 | 46.4 | 4.0 | 0.6 | 0† : 1 : 1 |
| Gasoline .. | 1.25 | 1% Waste | 144 | 222 | 793 | 41.5 | 19.5 | 3.4 | 5* : 1 : 1 |
| $CuSO_4$.... | 0.4 | 0.04% " | 16 | 26 | 185 | 18.4 | 3.1 | 2.3 | 1.6* : 1 : 1 : 1 |
| $Na_3AsO_4$... | 0.008 | 0.008% " | 140 | 353 | 722 | 44.1 | 9.9 | 1.9 | 0.04* : 1 : 0.7 |
| " ... | 0.02 | 0.008% " | 29 | 54 | 365 | 59.0 | 7.5 | 2.9 | 0.1* : 1 : 0.7 |

† By volume. * Grams.

*Gasoline.*—Repeated addition of gasoline to sludge appears to reduce the toxic action of gasoline to some extent. This is indicated by some of the results obtained with a seed resulting from the digestion of mixtures of fresh solids—ripe sludge which had received 0.19 per cent gasoline, on the basis of fresh solids. The sludge used for seeding (containing 0.2 per cent gasoline) was taken from a mixture which digested at practically the same rate as the controls. The amount of gasoline was increased to 1.25 per cent; the time required for the digestion of this mixture was about 80 days, whereas sludge containing 1 per cent gasoline, without seed previously produced by digestion with gasoline, required 120 days for digestion. Putting it differently: 80 days were required to produce 500 cc. of gas per gram of volatile matter in the 1 per cent mixture (without acclimated seed) and only 50 days to produce the same amount of gas, when 1.25 per cent gasoline was added to the mixtures containing seed previously produced in the presence of gasoline. Nevertheless, the amount of gasoline added retarded gasification materially as compared with the controls, which required only 19.5 days to produce the same quantity of gas.

*Copper Sulphate.*—In previous experiments, additions of 0.04 per cent $CuSO_4$ showed little retarding effect, whereas addition of 0.08 per cent $CuSO_4$ resulted in production of very little gas, but the percentage volatile matter reduction in both cases was equal to the controls. The quantities of $CuSO_4$ were then increased. The results from the mixture receiving 0.4 per cent $CuSO_4$, on the basis of the fresh solids, seeded with sludge which had previously received 0.04 per cent, are presented as the borderline for maximum addition. The addition of this large quantity of $CuSO_4$ resulted in very slow digestion. Only 18 per cent of the volatile matter was reduced in 80 days and only 150 c.c. of gas per gram of volatile matter had evolved during that time. However,

comparing the results with non-acclimated mixtures receiving 0.08 per cent $CuSO_4$, gas production was much greater, so that after 60 days digestion time the gas produced from the mixtures with five times higher amounts of $CuSO_4$ was nearly double that of the mixtures with the lower $CuSO_4$ concentration.

*Sodium Arsenate.*—Repeated use of seed produced by the addition of sodium arsenate increased gas production only slightly, but appeared to have less and less effect on volatile matter reduction. As a matter of fact it seemed gradually to aid liquefaction, as measured by the standard method of volatile matter determination. Part of this apparent increase in liquefaction may be due to accumulation of liquefied material in the seed sludge, but calculations show that the entire increase could not be accounted for by the actual accumulation. It is probable that certain arsenate-tolerant bacteria increased gradually. It is also a well known fact that specific organisms can decompose arsenates. With increased removal of arsenate the more resistant liquefiers would increase. The small increase in gas production would seem to indicate that sodium arsenate received continuously in small doses would do relatively little harm to the digestion process, but that equally small quantities received occasionally would interfere seriously.

*Oil Waste.*—Using sludge produced from mixtures to which 1 per cent of oil, by volume, had been added as seed material and quantities of oil similar to those previously added to the sludge (varying from 0 to 250 c.c. per liter sludge) volatile matter reduction and gas production were determined. The results of greatest interest are those concerned with gas production and gas composition. Digestion was retarded considerably with quantities of oil above 25 c.c. per liter, or rather, gas production continued for a much longer time. The quantities of gas produced per gram of fresh solids added after different lengths of time are shown in Table VIII. After 35 days, when the

TABLE VIII.—*Quantities of Gas Produced per Gram Fresh Solids by Mixtures to Which Waste Oil Was Added*

Results in Cubic Centimeters

| Oil Added | 35 Days | 48 Days | 101 Days | 160 Days |
|---|---|---|---|---|
| 0 | 592 | 615 | — | — |
| 10 | 717 | 737 | — | — |
| 25 | 713 | 740 | — | — |
| 50 | 755 | 810 | 885 | — |
| 100 | 750 | 796 | 895 | — |
| 250 | 442 | 545 | 835 | 1032 |

control mixture had stopped producing measurable quantities of gas, the mixtures with oil had produced from 18 to 20 per cent more gas, with the exception of the mixture with the largest quantity of oil. On continued incubation some more gas was produced by the mixtures with the higher amounts of waste oil. It required about 75 days before the

mixture with the highest quantity of oil added had produced the same quantity of gas as the other sludge-oil mixtures. In every instance the peak gas production of the sludge-oil mixtures came a few days later than from the control, but gas production was sustained longer at a higher level. The compositions of the gases were again very constant in all cases, except the mixtures with the highest quantities of oil. A few of the results are given in Table IX for illustration. From the

TABLE IX.—*Gas Composition of Different Mixtures (Expressed in Percentage by Volume)*

| Oil Added | After 13 Days | | | After 20 Days | | | After 35 Days | | | After 56 Days | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $CO_2$ | $O_2$ | $CH_4$ | $CO_2$ | $O_2$ | $CH_4$ | $CO_2$ | $O_2$ | $CH_4$ | $CO_2$ | $O_2$ | $CH_4$ |
| 0 | 18.4 | 0.1 | 74.6 | 16.0 | 0.2 | 81.2 | 15.6 | 0.1 | 82.1 | — | — | — |
| 1 | 17.8 | 0.2 | 77.4 | 15.9 | 0.1 | 78.4 | 13.0 | 0.1 | 82.6 | — | — | — |
| 2.5 | 18.6 | 0.1 | 79.6 | 15.7 | 0.2 | 80.4 | 13.5 | 0.2 | 85.1 | — | — | — |
| 5.0 | 22.0 | 1.4 | 67.1 | 12.6 | 0.5 | 83.2 | 13.9 | 0.0 | 70.5 | 14.0 | 0.1 | 84.0 |
| 10.0 | 22.1 | 0.6 | 0 | 16.4 | 1.0 | 72.0 | 12.8 | 1.4 | 69.2 | 13.2 | 0.1 | 78.2 |
| 25.0 | 22.9 | 0.1 | 0 | 24.4 | 0.2 | 70.8 | 19.3 | 0.4 | 80.2 | 15.2 | 0.2 | 80.0 |

standpoint of gas production it appears that waste oil may increase the quantity of gas produced, but excessive quantities of oil retard digestion when the oil is received either intermittently or continuously. However, from the standpoint of sludge drying, waste oil is decidedly detrimental. The drainability is decreased, and with larger quantities of oil, even when considerably more gas has evolved than from the mixtures without oil, the sludge has a sticky, greasy consistency which remains for an indefinite length of time. Attempts to dry such digested sludge by evaporation on a steam bath failed with the larger quantities of oil completely and with the smaller quantities, pieces of sludge remained which were not easily broken up. Such sludge would even be difficult to handle when used for fuel or to be disposed of by incineration.

*Sulphuric Acid.*—As could be expected, the results obtained with repeated use of digested sludge for seed material which had received sulphuric acid were not materially different from those obtained when acid was added previously.

## DISCUSSION

The different trade wastes added to the digesting fresh solids-ripe sludge mixtures exerted a retarding influence only with comparatively large quantities. Toxic substances like sodium arsenate and copper sulphate would be expected to have a pronounced effect, and it appears that the discharge of a batch of poisonous material into the sewer may upset biological digestion activities. When the quantities are small and regularly discharged, retardation of gas formation would first be noticeable. The organisms responsible for liquefaction are apparently

less affected than those producing gas. In general it is rather surprising how much trade waste will be tolerated.

The concentrations of sodium arsenate amounting to 0.08 and 0.04 per cent by volume were extremely toxic. Reducing the quantities to 0.02 decreased toxicity somewhat, but even small quantities of 0.008 per cent retarded gasification from 15 to 20 days.

The effect of 1.0 per cent or more by volume of gasoline was rather unexpected. Experiments with similar quantities of waste crank case oil indicated considerably less retardation of gasification. When more than 0.2 per cent gasoline by volume of the fresh sludge was added, the retarding effect was noticed, while with 1.0 per cent added, the digestion time was at least doubled. Eventually the same quantities of gas were produced, even with 1.25 per cent gasoline, but seeding with previously digested gasoline-sludge did not accelerate digestion.

Although crank case oils and gasoline are mineral oils, it appears that a distinction must be made between the two as far as their effects on the rate of digestion and gas production are concerned. With crank case oil, greater scum formation was apparent, and gas bubbles were held together to a greater extent, causing a slight froth or foam to be formed when gas production was active. With gasoline additions gas bubbles escaped easier, resulting in less foam.

Whatever waste was added, the amounts of hydrogen sulphide in the gas evolved were increased. It is natural to expect that with increased liquefaction the $H_2S$ production should increase.

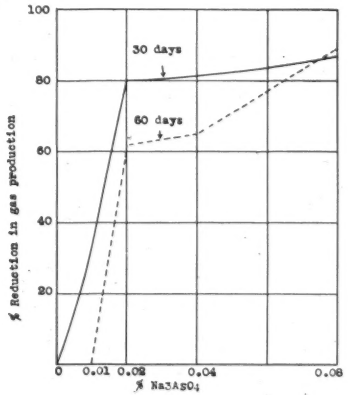


FIG. 2.—Decrease in gas production with increasing quantities of sodium arsenate.

Even continuous arrival of small quantities of sodium arsenate would interfere with the digestion processes and be harmful to gas production. The effect of this poison on gas production is clearly shown in Fig. 2, where the 30 and 60 day total gas production per gram of volatile matter added is plotted in percentage reduction of the quantity of gas produced by the controls.

In some cases an increase in volatile matter reduction is indicated. The apparent reduction of volatile matter shows liquefaction rather than complete destruction or mineralization in any sense. Much of this liquefied material volatilizes and is lost on drying for solids determinations. Since the organic matter must be "liquefied" before it can be gasified, the poisons interfere only partly with the decomposition processes, but this interference results only in the absence of gas. The toxicity of sodium arsenate prevailed even throughout repeated usage of sludge, indicating that no great acclimatization took place, so that only small quantities of this poison can be tolerated under any system of operation.

Although total gas production is not necessarily in all cases the best index for digestion, a change in the rate and volume produced gives a good picture of the degree of acclimatization. In Table X comparisons

TABLE X.—*Increase (+) or Decrease in Gas Production Caused by Waste With and Without "Acclimated Sludge"*

| Waste | Waste Added to Ripe Sludge Per Cent | Reduction, (60 Days) Per Cent | Waste Added to Acclimated Sludge Per Cent | Reduction, (60 Days) Per Cent |
|---|---|---|---|---|
| Sodium Arsenate | 0.008 | +11 | 0.008 | + 5 |
| | 0.02 | 62 | 0.02 | 36 |
| | 0.04 | 65 | 0.04 | 43 |
| | 0.08 | 88 | 0.08 | 52 |
| Copper Sulphate | 0.04 | 10 | 0.04 | 1 |
| | 0.08 | 86 | 0.08 | 27 |
| | — | — | 0.40 | 86 |
| Gasoline | 0.20 | + 1 | 0.40 | 2 |
| | 1.00 | 43 | 1.25 | 13 |
| | 2.00 | 81 | 2.00 | 75 |
| Oil | 1.00 | +29 (1) | 1.00 | +14 (2) |
| | 2.50 | +24 (1) | 2.50 | +14 (2) |
| | 5.00 | +18 (1) | 5.00 | +24 (2) |
| Sulphuric Acid | 0.25 | +11 | 0.25 | + 8 |
| | 0.50 | 98 | 0.50 | 92 |

(1) 35 days, (2) 48 days digestion.

are made between the total quantities of gas per gram of volatile matter in the fresh solids added to ripe sludge and the gas produced on the same basis by the "acclimated" sludge having previously been digested with the same quantities of poisons. Gas production is shown after 60 days digestion unless otherwise indicated. In all instances, gas production was increased when the poisons were added to acclimated sludge, with the exception of sulphuric acid. In most cases there was still a material percentage reduction over the controls, indicating that

there are rather definite limits, and larger quantities will be detrimental to the digestion processes. From all the work done the impression stands out that poisons received regularly in small quantities can be handled, but are rather dangerous to admit when optimum conditions for digestion are not available.

### *B.* Effect on Thermophilic Digestion

In a previous paper (1) the method of obtaining thermophilic sludge from fresh solids and the addition of fresh solids and trade wastes to this seed material have been described.

A number of the mixtures with addition of intermediate quantities of poison produced results similar to those shown for mesophilic digestion. Mixtures with the larger quantities of copper sulphate and sodium arsenate produced practically no gas, but showed some volatile matter reduction, probably due to liquefaction. With smaller quantities of poison the behavior of the mixtures was similar to those recorded under mesophilic conditions and if any difference existed it appeared that the thermophilic sludge was slightly more sensitive to these poisonous materials.

In the case of gasoline the toxicity was again very evident. A few of the condensed results indicate such toxicity:

| Gas Added, Per Cent | Vol. Mat. Red., Per Cent | Gas per Grm. V. M. Added, C.C. | To Produce 90% of Gas, Days | pH at End |
|---|---|---|---|---|
| 0 | 41.2 | 496 | 14 | 7.9 |
| 5 | 0.3 | 38 | 27+ | 7.2 |
| 10 | 0.2 | 42 | 27+ | 7.2 |

No effort was made to determine the entire time required for digestion of the mixtures receiving gasoline, but the mixtures were incubated for 27 days, or nearly double the time required for the controls to produce 90 per cent of the total gas. The 5 per cent gasoline added would be equivalent to about 15 p.p.m. in an average sewage of about 200 p.p.m. suspended solids, with a removal of 50 per cent, provided the gasoline settled with the sludge and no gasoline was present in the seed material. No information is available to indicate how long the gasoline would persist in the mixtures.

The effect of waste crank case oil was determined only with smaller quantities. The behavior of the mixtures in regard to volatile matter reduction and gas production was again much the same as for the mixtures digested under lower temperature conditions. Since presentation of the results would mean repetition they are omitted.

For the purpose of determining the effect of the different poisons on the dewatering of digested sludge a series of tests were made to compare the amounts of liquid which could be removed under standard

conditions. The standardized filters were operated for 30 minutes with vacuum equal to 21 inches of mercury. No conditioning chemicals were added to the sludges filtered at the end of the digestion periods. Some of the condensed results, showing the amounts of filtrate after 5 and 30 minutes, together with the color and pH of filtrate, and the percentage solids and ash of the mixtures are shown in Table XI. It

TABLE XI.— *Quantities of Filtrate Obtained From Thermophilic Digested Sludge Mixtures (Averages of at Least 3 Samples)*

| Waste | Filtrate | | Solids Per Cent | Ash Per Cent | pH | Color of Filtrate |
|---|---|---|---|---|---|---|
| | 5 Min. | 30 Min. | | | | |
| None | 28 | 150 | 2.66 | 44.8 | 7.5 | Black |
| Sod. Arsenate, 0.02% | 23 | 170 | 3.27 | 43.5 | 7.6 | Yellow |
| Sod. Arsenate, 0.04% | 15 | 156 | 2.41 | 44.4 | 7.8 | Yel. blk. |
| Copper Sulfate, 0.8% | 13 | 72 | 3.35 | 39.6 | 7.3 | Black |
| Gasoline, 1% | 30 | 142 | 2.72 | 44.2 | 7.6 | Black |
| Gasoline, 5% | 26 | 132 | 2.95 | 39.2 | 7.6 | Yel. blk. |
| Gasoline, 10% | 16 | 105 | 2.99 | 40.5 | 7.8 | Pale yellow |
| Waste Oil, 1% | 6 | 51 | 2.75 | 34.1 | 7.8 | Black |
| Waste Oil, 2.5% | 3 | 32 | 2.86 | 29.2 | 7.8 | Black |

is of interest that the addition of small quantities of sodium arsenate did not reduce the rate of dewatering, although digestion was impaired, whereas another poison, copper sulphate, caused much poorer dewatering. With increasing quantities of gasoline the amount of water released decreased gradually and waste oil made the mixtures very difficult to dewater. In general, the types of waste experimented with affected dewatering and drying of the digested sludges adversely.

## ODORS

There is a general relationship between hydrogen sulphide present in the gases produced and the odor of the sludges, but under thermophilic conditions the ammoniacal odors together with the higher temperatures intensify the odors, in spite of the fact that less hydrogen sulphide may be produced. The intensity of the odors varied also with the degree of digestion. In the case of poisonous substances, digestion was retarded and strong odors were prevalent even after a considerable period of digestion. A comparison of the tarry, gaseous odor of well digested sludge with the odors of the different mixtures receiving poisons, showed that the odors were either intensified or masked by the substance added. The odors of digested mesophilic sludge and thermophilic sludge in the presence of the materials added have been compared in the form of brief notes (Table XII). Some of the materials, having in general less effect on thermophilic mixtures, caused relatively greater odor production than similar mixtures digested under mesophilic conditions.

TABLE XII.—*Odors of Digested Sludges at Time When Experiments Were Terminated*

| Waste Added | Mesophilic Sludge | Thermophilic Sludge |
|---|---|---|
| Sod. Arsenate, 0.04% | Slight putrescent | Strongly putrescent |
| 0.08% | Putrescent | Vile |
| $CuSO_4$, 0.04% | Less than controls | Slight putrescent |
| 0.08% | " " " | " " |
| Gasoline, 0.2% | Slight gasoline | Gasoline |
| 1.0% | " " | Gasoline and ammoniacal |
| 2.0% | Distinct gasoline | Gasoline and strongly ammoniacal |
| Waste Oil, 1.0% | Ripe sludge | Ripe sludge and slight ammoniacal |
| 2.5% | " " , oily | Ripe sludge, oily |
| $H_2SO_4$, 0.25% | Ripe sludge | Slight putrescent |
| 0.50% | Strong putrescent ($H_2S$) | Strong putrescent ($H_2S$) |

## GENERAL CONCLUSIONS

The general conclusions drawn from the sludge digestion experiments conducted in the presence of poisons, oils and acid conducted at high and low temperature are:

*Mesophilic.*—(*a*) *Poisons,* such as sodium arsenate and copper sulphate, retard sludge digestion even when small quantities are added. Gas production is more affected than liquefaction. The rate of dewatering may or may not be reduced, depending upon the type and quantity of poison added. Odors are intensified.

(*b*) *Oils,* such as crank case waste, appear to stimulate gas production but increase digestion time. Dewatering is greatly reduced. Even small quantities of gasoline are very toxic, reducing gas production and increasing digestion time. Odors are masked in spite of larger quantities of hydrogen sulphide produced.

(*c*) *Acids* in small quantities have little effect on gas production and digestion time, but produce more odors. Larger quantities practically inhibit digestion or prevent gasification, changing the process to liquefaction.

Sewage sludge appears to be capable of limited "acclimatization" with poisons, and more with oils, thereby becoming capable of tolerating somewhat larger quantities of waste with less detrimental effects.

*Thermophilic.*—Sewage sludge mixtures receiving wastes require a shorter time for digestion at high than at low temperatures. Thermophilic sludge appears to be more sensitive to poisons than sludge digested under mesophilic conditions. Sludge-waste mixtures produce somewhat less gas when incubated at high temperatures. The heat value of the gas is not materially different than that of gas produced at low temperatures. Less hydrogen sulphide is produced, but odors of the sludge are more pronounced. The drainability of the sludge is greatly affected when digested in the presence of waste oils and copper sulphate, but gasoline, sodium arsenate and sulphuric acid have little effect.

## Summary

Laboratory digestion experiments at high and low temperatures were made on a number of sewage sludge and waste mixtures, the latter including poisons, mineral oils and acids. The purpose was to determine the relative effects of the different wastes added in varying quantities on (1) the digestion time, (2) gas production, (3) heat values of gases produced, (4) odors, (5) drainability, and (6) "acclimitization" of the mixtures to specific wastes. The different mixtures (except those with $H_2SO_4$) were incubated at 20° C and 50° C; solids reduction, gas production and hydrogen sulphide evolution determined and other relevant observations made.

The results show that under mesophilic conditions comparatively small quantities of poisons, acids and oils caused retardation or inhibited digestion, affecting gasification to a greater extent than liquefaction. Gas production may be increased by small quantities of crank case oil, but the time required for completion of digestion was greatly increased. Additions of wastes caused odors to increase. Sludge mixtures could be acclimated only to a limited extent.

Sludge mixtures digested at higher temperatures were more sensitive to poisons, but less to oils and acids, than mixtures receiving similar quantities of wastes and digested at low temperatures. The time for thermophilic digestion was shorter, but somewhat less gas was produced. Odors of the sludge were intensified to different degrees by the varying quantities of wastes added, but less hydrogen sulphide was present in the gas. Drainability of the digested mixtures was poorer.


## Reference

1. Rudolfs and Setter, *This Journal*, 9, 549–568 (1937).

## Acknowledgment

Parts of the laboratory work were carried out by Messrs. Setter, Lacy, Henderson and other members of the staff.

# EFFECT OF STIRRING OF SLUDGE ON VACUUM FILTRATION

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Many factors affect the vacuum filtration of sewage sludge. Among those that have been investigated are the pH value and the solid content, the temperature, the percentage of volatile matter, the amino-ammonia nitrogen concentration and the age of the sludge. Moreover, the results obtained with varying quantities of different coagulants have been compared. These experiments have contributed much to the knowledge of sludge filtration. One phase of sludge conditioning that it has been considered desirable to investigate relates to the handling and treatment of sludge from the time it is drawn from tanks or digesters until it reaches vacuum filters. During the early experiments on the vacuum filtration of sludge at Baltimore (1) in 1931 and 1932, tests indicated that the best results were obtained by filtering the sludge as soon as possible after the addition of the coagulant. These tests have been continued for the purpose of answering the following questions:

1. What effect will the stirring of sludge prior to its being coagulated have on filtration rates?
2. How will filtration rates be affected if a coagulant is mixed with sludge for varying periods of time and (*a*) filtered at once or (*b*) allowed to stand quiescent before being filtered?

The experiments have indicated that the stirring of sludge before coagulation reduced the rates of filtration. Furthermore, stirring the sludge for any appreciable time after the coagulant had been added was detrimental to high filtration rates. Allowing the coagulated sludge to remain quiescent before being filtered in general reduced the rate of filtering raw sludge and increased the rate of filtering semi-digested and digested sludge.

## Experimental Procedure

Tests were made using raw, semi-digested and digested sludge, which materials were obtained at the Baltimore sewage treatment works. In each case the sludge was coagulated with ferric chloride. Different amounts of this chemical were used to see how the rate of filtration varied with the amount of coagulant. The sludge was filtered in a 9-cm. Buchner funnel, placed on a filter flask. A vacuum was applied to the flask by means of a Schuette and Koerting laboratory tap aspirator. A detailed description of the routine followed is given in an article by Genter (2).

All of the experiments were made in duplicate. For the sake of brevity only one set of the tests is given. Except for minor discrepancies, the results of the two groups of tests were reasonably alike.

*Stirring Sludge Prior to Coagulation.*—The first group of experiments consisted of stirring the three types of sludges prior to the addition of coagulant. The sludge was placed in a 2-litre glass jar, and

TABLE I.—*Characteristics of Sludges Stirred at 1,600 Rev. per Min.*

| Type of Sludge | Volatile Solids Dry Basis, Per Cent | Solids, Per Cent | pH Value |
|---|---|---|---|
| Raw | 81.0 | 4.1 | 5.5 |
| Semi-digested | 60.3 | 6.7 | 8.0 |
| Digested | 56.0 | 5.4 | 8.0 |

stirred by means of a motor-driven propeller, which had a speed of 1,600 rev. per minute. The characteristics of the three kinds of sludge are given in Table I. The pH value of the semi-digested and digested material was quite high, as stirring caused the escape of carbon dioxide.

The raw sludge was stirred for various periods of time up to a maxi-

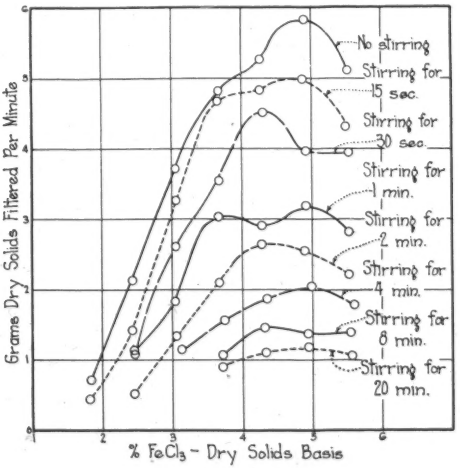
Grams Dry Solids Filtered Per Minute
% FeCl3 - Dry Solids Basis
No stirring
Stirring for 15 sec.
Stirring for 30 sec.
Stirring for 1 min.
Stirring for 2 min.
Stirring for 4 min.
Stirring for 8 min.
Stirring for 20 min.

FIG. 1.—Effect on filtration of stirring raw sludge before coagulation.

mum of 20 minutes. The greatest production of filter cake was obtained with sludge that was not stirred. The longer the period of stirring, the less was the quantity of cake produced. The results are given in Fig. 1. Similar results were obtained when filtering semi-digested and digested material (Figs. 2 and 3) after stirring. A com-

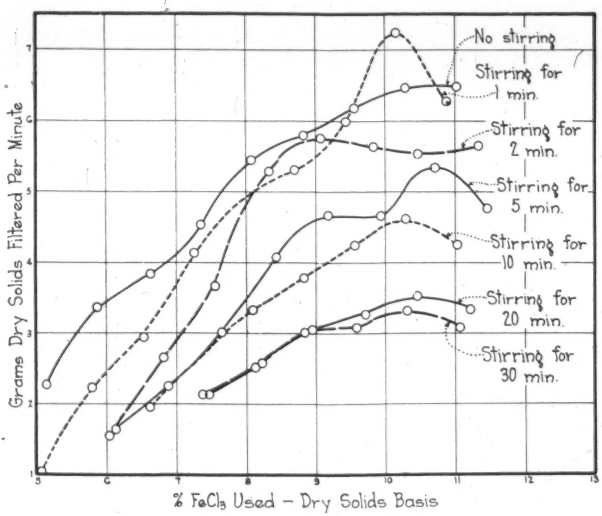
No stirring
Stirring for 1 min.
Stirring for 2 min.
Stirring for 5 min.
Stirring for 10 min.
Stirring for 20 min.
Stirring for 30 min.
Grams Dry Solids Filtered Per Minute
% FeCl3 Used – Dry Solids Basis

FIG. 2.—Effect on filtration of stirring semi-digested sludge before coagulation.

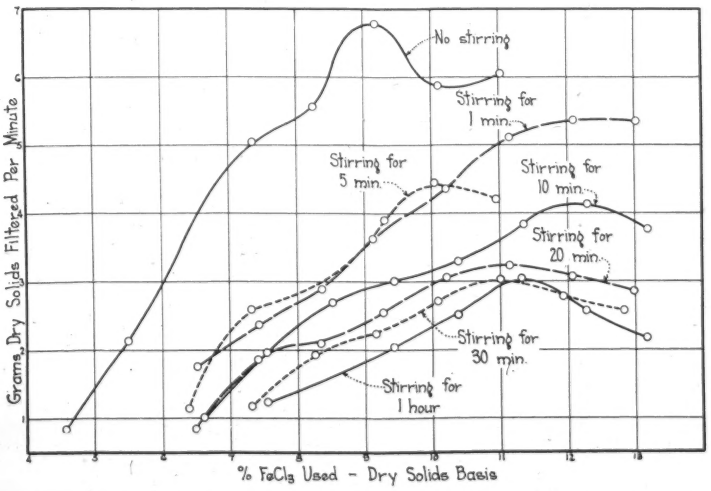
No stirring
Stirring for 1 min.
Stirring for 5 min.
Stirring for 10 min.
Stirring for 20 min.
Stirring for 30 min.
Stirring for 1 hour
Grams Dry Solids Filtered Per Minute
% FeCl3 Used – Dry Solids Basis

FIG. 3.—Effect on filtration of stirring digested sludge before coagulation.

parison of the findings indicates that the cake production when filtering semi-digested and digested sludge was affected less by stirring than raw material.

*Stirring Sludge Containing Coagulant.*—The next group of experiments consisted of adding ferric chloride to raw, semi-digested and

TABLE II.—*Characteristics of Sludges Stirred at 90 Rev. per Min.*

| Type of Sludge | Characteristics of Sludge | | | $FeCl_3$ Used, Dry Sludge Solids Basis, Per Cent |
|---|---|---|---|---|
| | Volatile Matter, Dry Basis, Per Cent | Solids, Per Cent | pH Value | |
| Raw | 81.8 | 4.4 | 6.0 | 2.28 |
| Semi-digested | 58.1 | 5.6 | 7.1 | 8.97 |
| Digested | 56.0 | 5.7 | 7.5 | 8.7 |

digested sludge, stirring the material for various periods of time, followed by filtering the sludge after it had stood for different lengths of time. Table II gives the characteristics of the sludge and the amounts of coagulant used. The sludge was stirred with a motor-driven propeller, operating at 90 rev. per min., for intervals of from 15 seconds to

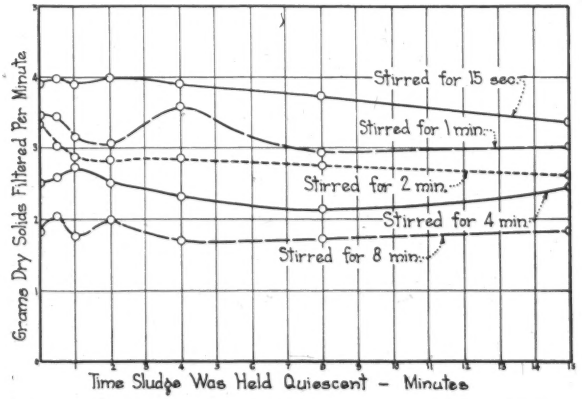
Grams Dry Solids Filtered Per Minute
Time Sludge Was Held Quiescent - Minutes
Stirred for 15 sec.
Stirred for 1 min.
Stirred for 2 min.
Stirred for 4 min.
Stirred for 8 min.

FIG. 4.—Effect on filtration of stirring raw sludge after coagulation and holding material quiescent before filtering.

8 minutes. The sludge was then filtered after it had stood for different times up to 15 minutes. Some of the material, however, was filtered after standing for as much as 6 hours.

The results when filtering raw sludge are shown in Fig. 4. The greatest cake output was obtained when the sludge was stirred for 15 sec. and filtered after standing for a period not exceeding 4 minutes.

After that time the filtration rate dropped from 3.9 grams of dry solids per minute to 3.37 grams at the end of 15 min. and 0.83 grams after 5 hours (Fig. 5). Somewhat similar results were obtained when the

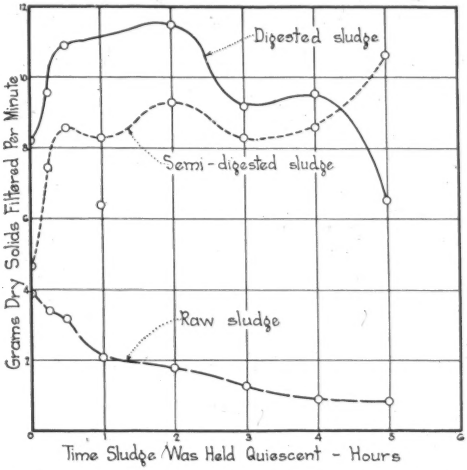


FIG. 5.—Effect on filtration of stirring sludge after coagulation and holding material quiescent for several hours before filtering.

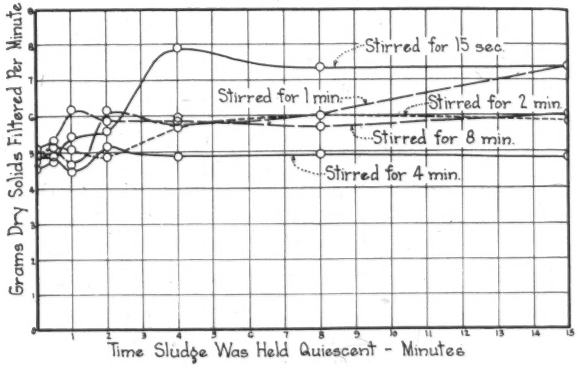
Stirred for 15 sec.
Stirred for 1 min.
Stirred for 2 min.
Stirred for 8 min.
Stirred for 4 min.
Grams Dry Solids Filtered Per Minute
Time Sludge Was Held Quiescent - Minutes

FIG. 6.—Effect on filtration of stirring semi-digested sludge after coagulation and holding material quiescent before filtering.

sludge was stirred for 1 and 2 minutes. Stirring the sludge for 4 and 8 minutes gave increasingly lower filtration rates.

Fig. 6 shows the filtration rates when semi-digested sludge was stirred and then filtered. When the coagulated sludge was stirred for

varying periods of time up to 8 minutes, the filtration rate remained about the same. In some instances letting the sludge remain quiescent before filtering increased the cake production. The filtration rate of the sludge which was stirred for 15 sec. increased from 4.64 grams of dry solids per minute when the sludge was dewatered immediately after stirring to 7.4 grams when the sludge was held for 15 minutes and to 10.6 grams when the material was held for 5 hours.

The results obtained when stirring and filtering digested sludge are given in Fig. 7. It is apparent that continued stirring of the coagulated

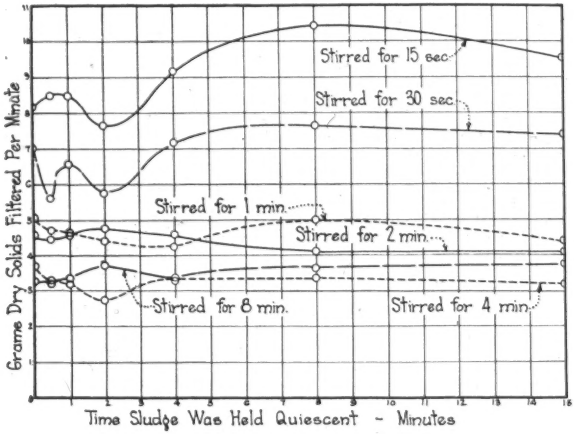
Grams Dry Solids Filtered Per Minute
Time Sludge Was Held Quiescent - Minutes
Stirred for 15 sec.
Stirred for 30 sec.
Stirred for 1 min.
Stirred for 2 min.
Stirred for 8 min.
Stirred for 4 min.

FIG. 7.—Effect on filtration of stirring digested sludge after coagulation and holding material quiescent before filtering.

material is detrimental to high rates of filtration. The sludge that was stirred for 15 sec. and filtered immediately yielded 8.2 grams of dry solids per minute. Stirring for 8 minutes reduced this yield to 3.3 grams per minute. Holding the sludge that was stirred for 15 seconds increased the output. For example, the yield was 10.42 grams per minute when the sludge was held 8 minutes and 11.5 grams when the material was held 2 hours.

## CONCLUSIONS

The interpretation of small scale laboratory investigations should be made as a rule with great care. However, the following tentative statement has been made regarding the experiments:

1. Raw, semi-digested and digested sludge that was stirred with a propeller rotating at 1,600 rev. per min. prior to coagulating the material became more difficult to filter as the stirring period was increased.

2. When raw and digested sludge to which a coagulant had been added was stirred with a propeller revolving at 90 rev. per min., the

production of cake decreased as the period of stirring increased. Semi-digested sludge was only slightly affected by stirring. Holding the raw sludge for any appreciable time after stirring before filtering, decreased the cake yield. Holding the semi-digested and digested sludge as a rule increased the yield.

The Baltimore sewage works is under the general supervision of B. L. Crozier, chief engineer, Department of Public Works, and G. E. Finck, sewerage engineer, with G. K. Armeling, superintendent. J. W. Bushman, junior chemist, assisted in the laboratory work.

### References

1. C. E. Keefer and E. C. Cromwell, "The Dewatering of Sludge by Vacuum Filtration," *This Journal*, **4**, 929 (1932).
2. A. L. Genter, "Adsorption and Flocculation as Applied to Sewage Sludges," *This Journal*, **6**, 689 (1934).

# ADJUSTMENT OF pH VALUE OF SEWAGE BY MEANS OF CARBON DIOXIDE

By T. Chujo

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Because of the large amount of industrial waste in the sewage at the Kisshoin Experimental Sewage Disposal Plant at Kyoto (Fig. 1), which is of the activated sludge type, conditions are not favorable to treatment of the sewage by this process. To obtain even fair results, it is necessary to adopt special means and precautions. In studying

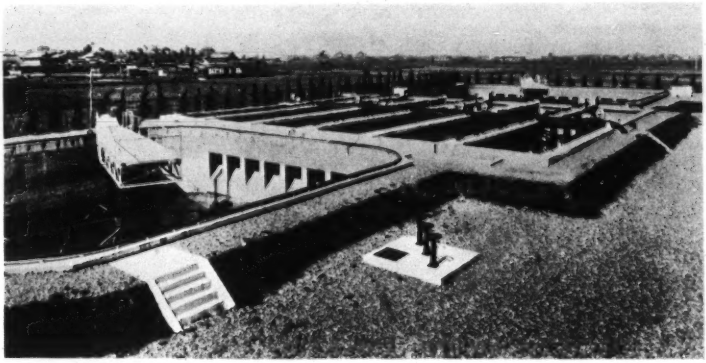

Fig. 1.—Kyoto Plant. Primary clarifier, aerators and secondary clarifier.

the sewage it was found that the chief difficulty was caused by strong acid or alkali wastes present in the sewage. These flows are very irregular and cannot be controlled at the plant. As a result the range of fluctuation of the pH value is very great and the concentration of trade wastes is invariably very high. This condition is very detrimental to the activity of aerobic bacteria upon which the success of the activated sludge process hinges. To create conditions favorable to the action of the aerobic bacteria meant that the pH value of the sewage had to be adjusted. This can be done by the use of various chemicals but because of the high cost of these chemicals in Japan and for other reasons, various problems will result in actual plant operation.

Carbon dioxide is known to affect hydrogen-ion concentration. Fortunately where sludge is digested anaerobically this compound is present in substantial quantities in the gas evolved from the digester. Experiments using this digester gas gave results similar to those when carbon dioxide gas was used.

At the Kisshoin Plant the sludge is heated by means of the gas from the digesters (Fig. 2). The exhaust gas from the burners using this

gas was examined and found to contain from 4.8% to 10.0% carbon dioxide. To use this gas in the adjustment of the pH value will require only a small initial expenditure and will not require any special operating expense. For this reason, it has been decided to make such an installation in the near future.

Design and operating characteristics of the Kisshoin plant are as follows:

| | |
|---|---|
| Area of Sanitary District | 19096 hectares (73.7 sq. miles) |
| Design population | 57,000 |
| Design flow | 112 litres per sec. (2.56 m.g.d.) |

The plant is of the activated sludge type, the sewage being presettled in mechanically cleaned clarifiers ahead of aeration. Excess

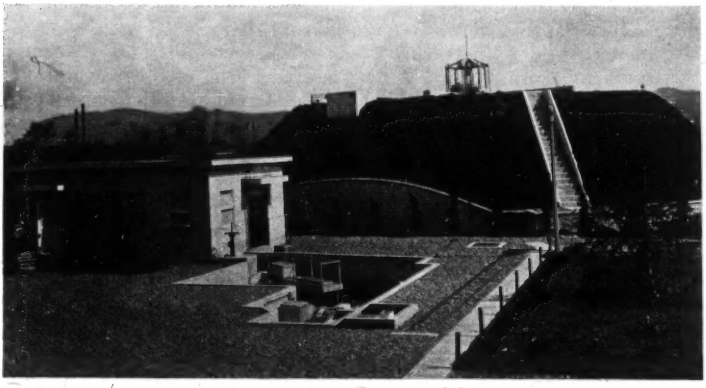

FIG. 2.—Screen house, detritor and digester.

activated sludge is wasted to the primary clarifiers. The combined sludges are digested in heated, mechanically stirred digesters. Aeration is carried out by a combination of air diffusion and paddles. The aeration period at design capacity is about six hours. By the use of this system of aeration, a considerable saving in the amount of air blown through the sewage is made possible. Ordinarily with straight air diffusion the volume of air used is about seven times the volume of sewage treated but by adopting the combination, the volume of air blown through the sewage is reduced about half. Upon metering the volume of sewage after the plant had been put into operation, the volume of flow was found to be 166.7 litres per second (3.80 m.g.d.), considerably more than the flow on which the plant was designed. The increase was due to the unexpectedly large amount of industrial waste entering the city sewers. A check up of the population showed that there were 6354 homes with 32,120 persons in this district. The amount of sewage contributed by this population was found to be 76.2 litres per second (1.74 m.g.d.). From the total flow it can be seen that the

amount coming from industrial plants was 90.5 litres per second (2.06 m.g.d.). The actual number of plants was found to be 126, distributed as follows:

| | |
|---|---|
| 67 | Textile Printing |
| 36 | Silk Printing |
| 3 | Textile Mangle |
| 20 | Others |

The amount of waste water from the plants in the district served by the Kisshoin Sewage Disposal Plant was metered for one month and found to average 3582 cubic meters (0.947 m.g.d.) per plant per month. (Of the 126 plants, the amounts contributed by 12 plants are not known.)

It is clear from the foregoing that most of the waste comes from the dye plants, the amount contributed by these plants comprising 54 per cent of the total flow. It may be said that probably in no other city in the world is there such a difficult sewage to treat. To make the treatment more difficult, the wastes from each of these dye plants differ radically from time to time. Variations in pH values are shown in Fig. 3.

The wide variation in the character of the sewage was a great hindrance to the growth and activity of the aerobic bacteria in the aeration tanks and lowered the efficiency of sludge digestion. To overcome the difficulty in the aerators the volume of air blow into the sewage was increased. This was effective to a certain extent but when the pH value exceeded 8.0 the difficulty increased. The volume of air required increased very rapidly and made the operating expense prohibitive. This made a further investigation of the treatment of the sewage necessary.

To combat this problem it was concluded that:

1. Each industrial plant be required to treat its waste before discharge to the city sewers, or
2. The entire sewage flow be neutralized by use of chemicals ahead of preliminary sedimentation basins or before the biological plant.

The first proposal would require each plant to shoulder its burden but in the Kisshoin Sanitary District there are many small independent family industries which make accurate control difficult. The second scheme would overcome this difficulty but would entail high operating cost.

Samples of sewages of high pH value were taken at the Kisshoin Disposal Plant and the pH values brought down to the neighborhood of 7.0 by use of chemicals. These samples were then tested at the laboratory by passing air through them to determine whether they were amenable to biological treatment. Fifty litres were used in all cases. To this, 15 per cent by volume of activated sludge was added. Aeration was accomplished by use of diffusion plates set at the bottom.

Some of the results obtained are shown in Tables I to V.

Table I shows the results of tests using sewage, the pH value of

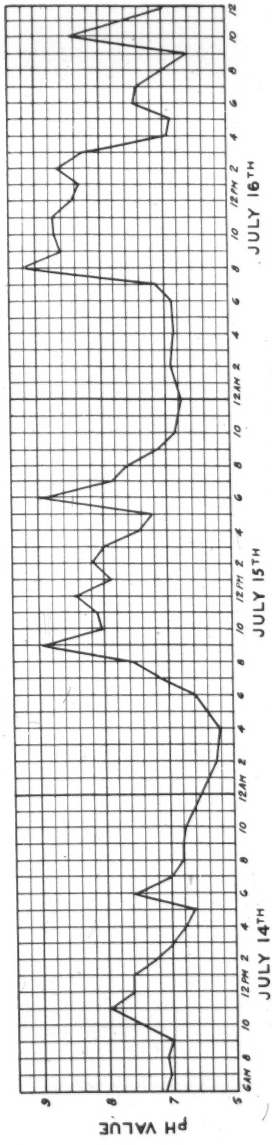


FIG. 3.—pH of sewage, Kisshoin plant, July 14–16, 1936.

TABLE I.—*pH Adjustment by Sulphuric Acid*

No. 1. Original Sewage
No. 2. After Adjusting pH

| | No. 1 | | | | | | No. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % | Volume of Air | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % |
| Original Sewage | Green Deep Turbid | 1.7 | 8.79 | 173 | | | | | | | |
| $\alpha$ Original Sewage | | | | | | | Deep Green Turbid | 1.6 | 7.07 | 169 | |
| After Aerating 1 hr. | Gray Turbid | 1.7 | 7.89 | 113 | 35 | 3 | Slightly Gray Turbid | 2.8 | 7.10 | 69 | 60 |
| " " 2 hrs. | Slightly Gray Turbid | 2.0 | 7.74 | 87 | 49 | 6 | " " " | 3.3 | 7.16 | 52 | 70 |
| " " 3 " | Slightly Transparent | 3.9 | 7.51 | 63 | 64 | 9 | Transparent | 10.0 | 7.14 | 32 | 82 |
| " " 4 " | " " | 5.2 | 7.44 | 48 | 72 | 12 | " | 12.9 | 7.14 | 30 | 83 |

which was 8.79 and also results on the same sewage where the pH value had been reduced to 7.00 by adding approximately 1 in 10,000 parts by weight of sulphuric acid. These two samples were treated by aeration under identical conditions. The amount of oxygen demand and the increase in transparency of the liquids were observed. For instance, after aerating for one hour using three volumes of air, it was found that the oxygen demand had dropped 35 per cent in the original sewage of high pH value, while that in the adjusted sample dropped 60 per cent.

In Table II results are tabulated of tests using a concentrated industrial waste with a strong odor. These were aerated for three hours using air to the extent of nine times the volume of sewage. The sample with the high pH value showed no indication of clarifying, but the color increased slightly, while the sample with the lowered pH value showed a drop of 63 per cent in the oxygen demand.

In Table III results are shown where ferric chloride was used for pre-treatment; 1/7000 part of ferric chloride was added to the sewage, the pH value of which was 8.68, which was reduced to 7.16 by the ferric chloride addition. The sample of original sewage of high pH value, and that in which the pH value had been adjusted, were tested under identical conditions. After passing air to the extent of three volumes per volume of sewage for one hour, the oxygen demand dropped 77 per cent in the sample whose pH value was adjusted by using ferric chloride. The original sewage did not show this drop in the oxygen demand after passing 12 volumes of air for 4 hours. The adjusted sample also showed better clarification.

Table IV shows the results obtained by using carbon dioxide gas. Sewage with a pH value of 8.93 was used. A second sample was adjusted by passing approximately 200 p.p.m. of carbon dioxide gas. This brought the pH value down to 6.89. After aerating for 4 hours using 16 volumes of air, the adjusted sample showed a drop in the oxygen demand of 86 per cent, while that of the original sewage dropped only 51 per cent. The original sewage did not clarify as readily as the sample whose pH value had been adjusted.

In Table V sewage with a pH value of 8.92 was used. After adding 200 p.p.m. of carbon dioxide the pH value was lowered to 6.87. After aerating for one hour using four volumes of air, the adjusted sample showed a 56 per cent drop in the oxygen demand while the original sample only showed a drop of 33 per cent. Aeration was continued for 2½ hours using 10 volumes of air in the original sewage but the oxygen demand reduction did not catch up with the treated sample.

Tests were repeated and similar results were obtained. They show the importance of adjusting the pH value to obtain good results in the activated sludge process where alkaline trade wastes are present, and that carbon dioxide can be used to obtain as good a result as when sulphuric acid or ferric chloride are used.

The cost of chemicals is an important consideration in selecting the type of material to adopt for pH value adjustment where conditions such as those at the Kisshoin plant are encountered. At this plant it

TABLE II.—*pH Adjustment by Sulphuric Acid*

No. 1. Original Sewage
No. 2. After Adjusting pH

| | No. 1 | | | | | | No. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % | Volume of Air | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % |
| Original Sewage | Blood Red Highly Turbid | 0.9 | 9.76 | 191 | | | | | | | |
| α Original Sewage | | | | | | | Blood Red Turbid | 1.1 | 7.02 | 186 | |
| After Aerating 1 hr. | Blood Red Turbid | 1.7 | 9.15 | 202 | — | 3 | Albuminous Turbid | 2.0 | 6.98 | 111 | 42 |
| " " 2 hrs. | " " " | 1.3 | 9.15 | 213 | — | 6 | " " | 1.9 | 7.23 | 94 | 51 |
| " " 3 " | " " " | 1.2 | 9.04 | 216 | — | 9 | " " | 2.1 | 7.29 | 71 | 63 |
| " " 4 " | " " " | 1.3 | 8.96 | 209 | — | 12 | Slightly Albuminous Turbid | 2.3 | 7.23 | 63 | 67 |

TABLE III.—*pH Adjustment by Ferric Chloride*

No. 1. Original Sewage
No. 2. After Adjusting pH

| | No. 1 | | | | | | No. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % | Volume of Air | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % |
| Original Sewage | Yellowish Gray Turbid | 1.1 | 8.68 | 164 | | | | | | | |
| α Original Sewage | | | | | | | Yellowish Gray Turbid | 1.5 | 7.16 | 154 | |
| After Aerating 1 hr. | Practically Transparent | 3.7 | 7.44 | 54 | 67 | 3 | Transparent | 5.8 | 7.19 | 38 | 77 |
| " " 2 hrs. | Practically Transparent | 5.7 | 7.58 | 45 | 73 | 6 | " | 7.4 | 7.22 | 29 | 82 |
| " " 3 " | Transparent | 8.3 | 7.55 | 42 | 74 | 9 | " | 9.3 | 7.25 | 27 | 84 |
| " " 4 " | " | 8.3 | 7.56 | 42 | 74 | 12 | " | 10.3 | 7.23 | 27 | 84 |

TABLE IV.—*pH Adjustment by Carbon Dioxide Gas*

No. 1. Original Sewage
No. 2. After Adjusting pH

| | No. 1 | | | | | | No. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % | Volume of Air | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % |
| Original Sewage | Pale Yellowish Brown | 0.9 | 8.93 | 179 | | | | | | | |
| α Original Sewage | | | | | | | Grayish Yellow | 1.0 | 6.89 | 171 | |
| After Aerating 1 hr. | Light Pink | 1.2 | 8.43 | 127 | 29 | 4 | Orange Transparent | 2.5 | 7.22 | 92 | 49 |
| " " 2 hrs. | " " | 1.3 | 8.14 | 116 | 35 | 8 | " " | 2.7 | 7.10 | 57 | 68 |
| " " 3 " | " " | 1.5 | 7.96 | 105 | 41 | 12 | Almost Transparent | 3.4 | 7.22 | 40 | 78 |
| " " 4 " | " " | 1.9 | 7.37 | 88 | 51 | 16 | Transparent | 5.7 | 7.25 | 25 | 86 |

TABLE V.—*pH Adjustment by Carbon Dioxide Gas*

No. 1. Original Sewage
No. 2. After Adjusting pH

| | No. 1 | | | | | | No. 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % | Volume of Air | Appearance | Turbidity | pH | Oxygen Demand P.P.M. | Reduction in Oxygen Demand % |
| Original Sewage | Yellowish Brown | 2.2 | 8.92 | 131 | | | | | | | |
| α Original Sewage | | | | | | | Pale Yellowish Brown | 2.0 | 6.87 | 127 | |
| After Aerating 1 hr. | Pale Yellowish Brown | 3.1 | 8.07 | 88 | 33 | 4 | Pale Yellow | 4.5 | 7.13 | 58 | 56 |
| " " 2 hrs. | Pale Yellow | 4.0 | 7.62 | 64 | 51 | 8 | Practically Transparent | 6.1 | 7.26 | 44 | 66 |
| " " 3 " | Practically Transparent | 5.8 | 7.22 | 50 | 62 | 12 | Transparent | 8.3 | 7.26 | 36 | 73 |
| " " 4 " | Transparent | 7.1 | 7.22 | 40 | 69 | 16 | " | 9.3 | 7.27 | 35 | 73 |

has been observed that the pH value of the sewage is about 8.70 for five hours per day. During this period the flow averages 600 cubic meters per hour (157,500 gal. per hr.). Results of a number of tests show that the following quantities of chemicals would be required to adjust the pH value of the sewage from 8.7 to approximately 7.0:

| | | | | | |
|---|---|---|---|---|---|
| $H_2SO_4$ (Sp. gr. 1.82) | 1:10,000 | parts by wgt. | (90 p.p.m. | 100% | $H_2SO_4$) |
| $FeCl_3 \cdot 6H_2O$ | 1: 7,000 | " " " | (60 p.p.m. | anhy. | $FeCl_3$) |
| $Fe_2(SO_4)_3 \cdot 9H_2O$ | 1: 7,000 | " " " | (102 p.p.m. | " | $Fe_2(SO_4)_3$) |
| $Al_2(SO_4)_3 \cdot 18H_2O$ | 1: 3,000 | " " " | (171 p.p.m. | " | $Al_2(SO_4)_3$) |

Based on the cost of chemicals in Japan as indicated below, the following would be the daily pre-treatment costs at the Kisshoin plant using acid, alum or ferric iron salts.

| Chemical | Quant. Req. per Day | Unit Cost* | Daily Cost* |
|---|---|---|---|
| $H_2SO_4$ (sp. gr. 1.82) | 300 kg. (660 lb.) | 0.053 yen per kg. ($15/T) | 16 yen ($4.80) |
| $FeCl_3 \cdot 6H_2O$ | 430 kg. (946 lb.) | 0.333 " " " (4.55¢/lb.) | 143 yen ($43.00) |
| $Fe_2(SO_4)_3 \cdot 9H_2O$ | 430 kg. (946 lb.) | 0.189 " " " (2.58¢/lb.) | 81 yen ($24.30) |
| $Al_2(SO_4)_3 \cdot 18H_2O$ | 1000 kg. (2200 lb.) | 1.11 " " " (1.5¢/lb.) | 110 yen ($33.00) |

* Value of yen taken at 30 cents in U. S.

The effect of carbon dioxide in reducing the pH value of the Kisshoin sewage is shown in Fig. 4. These and other tests indicate that to decrease the pH value from 8.7 down to 7.0, approximately one volume of pure carbon dioxide to ten volumes of sewage is required. If, therefore, commercial carbon dioxide were purchased at the Kisshoin plant for pH value adjustment, 300,000 litres of the gas would be required per day (10,600 cu. ft.). At the present market price of carbon dioxide in Japan of 60 yen per kg. (approx. 500 litres) the daily cost of treatment would be 360 yen ($108). This is higher than the cost of any of the other chemicals.

Fortunately the digester gas contains a high percentage of carbon dioxide which may be utilized. Furthermore, the methane content when burned in a boiler or an internal combustion engine will greatly increase the carbon dioxide available. At the Kisshoin plant, the digester gas averages 62.3 per cent methane and 33.7 per cent carbon dioxide. There are available in this gas 600 cubic meters per day (21,200 cu. ft.) of carbon dioxide. This is twice as much as is required. Where it is desired to utilize the gas for heating or power generation the gas must be collected after it has passed through the sewage.

Where the gas is utilized first in a boiler or a gas engine as at the Kisshoin plant, approximately 1700 cubic meters (59,700 cu. ft.) of carbon dioxide is provided per day. This exhaust gas contains from 5.0 to 10 per cent of carbon dioxide. Assuming that this exhaust gas is used, only about 18 per cent of the total quantity produced will be required per day. This will be equal to 4000 cubic meters per day (141,000 cu. ft.) of 7½ per cent $CO_2$ gas. As this will have to be added to the sewage during a five hour period, the diffusion system provided

will have to have a capacity of 13.33 cubic meters (470 cu. ft.) per minute. The equipment for this purpose will require only a small investment. For this operation we consider the "Turbo-mixer" to be satisfactory. Later tests performed with an experimental unit of this type showed that by feeding 7.5 per cent carbon dioxide content gas, the pH value was reduced from an average of 8.33 down to 7.12 in two minutes. In some cases the initial pH values were as high as 8.8. The ratio of gas to sewage volume in these tests was 1.04 to 1. Comparisons were made with diffusion of the flue gas through porous titles. It was found that the "Turbo-mixer" gave better results in two minutes than did the porous diffusers in an eight minute contact period.

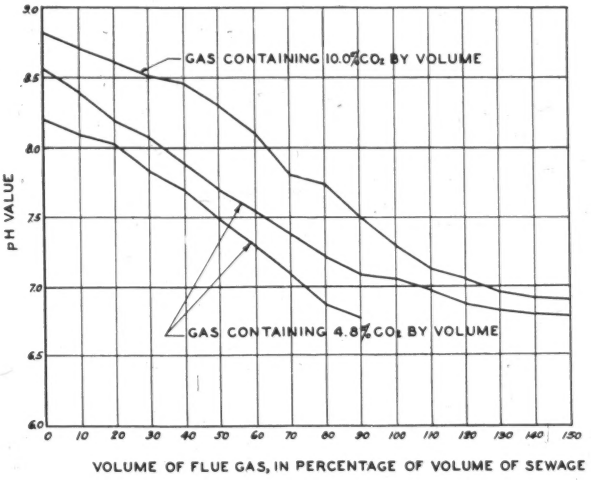


FIG. 4.—Effect of flue gas on pH of sewage, Kisshoin plant.

It is estimated that the power required to operate the "Turbo-mixer" will be about 8 H.P. Power costs at the Kisshoin plant are 2.0 sen (0.6 cent) per kw. hr. so that the daily operating costs using the plant flue gas for carbonation would be about 60 sen (18 cents). This does not include fixed charges which would probably not be greater than those where acid or metallic salts are used and where feeding and chemical storage equipment is required.

## CONCLUSIONS

1. Adjustment of the pH value of sewage is beneficial where alkaline trade wastes are present and where the sewage is treated by the activated sludge process.

2. Adjustment of the pH value to approximately 7.0 reduces the aeration period and amount of air required and also improves the quality of the final effluent.

3. Sulphuric acid, alum, ferric sulphate, ferric chloride and carbon dioxide may be used for pH value adjustment.

4. The utilization of digester gas as a source of carbon dioxide for pH value adjustment either before or after the gas is burned is recommended because of low operating costs.

5. At the Kisshoin sewage treatment plant, satisfactory operation of the activated sludge plant may be obtained if the pH value of the sewage is adjusted for five hours per day.

6. For the Kisshoin plant, cost of pre-treatment with alum, ferric chloride or ferric sulphate would be prohibitively high, ranging from 81 to 143 yen ($24.30 to $43.00) per day for a total daily flow of 3.8 m.g.d. The cost of sulphuric treatment would be 16 yen ($4.80) per day, whereas with the burned digester gas, the cost would be negligible, amounting to only 60 sen (18 cents) per day.

# Plant Operation

## COMPARISON OF SEWAGES OF OHIO MUNICIPALITIES ON BASIS OF OXYGEN REQUIREMENT PER CAPITA PER DAY *

By Bruce M. McDill

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The purpose of this discussion is to present data which have been collected of the per capita oxygen requirement expressed in pounds per day of Ohio municipal sewages. The five-day biochemical oxygen demand test is universally used to measure the oxygen demanding properties of sewages or, expressed another way, the oxygen required by sewages, hence the per capita values have been computed on the five-day basis. By use of conversion stability numbers, values may be computed for other time intervals ranging from one to twenty days, the latter being used for all practical purposes as the total oxygen demand or total oxygen requirement.

In a given sanitary sewage contributed by a fixed population the oxygen demand expressed in pounds, theoretically, should be constant, even though there may be relatively wide variances in the volumes of sewage flow and in the five-day B.O.D. contents expressed in parts per million. Therefore, the per capita per day oxygen requirement likewise should be constant under these conditions. On the other hand industrial wastes and perhaps to a lesser extent street washes from combined sewer systems will be readily reflected in per capita per day oxygen requirement values. For any municipal sewage, giving due consideration to the type of collection system and to the contributing factors within the community, it appears that the most constant characteristic is the pounds of oxygen demand per capita per day.

Calculation of the per capita per day oxygen requirement value is obtained from the following factors: tributary population, the five-day B.O.D. value as obtained from a representative sample of the crude sewage, and the volume of flow. To be confident of the per capita oxygen required figures, accuracy in obtaining all three factors is essential. Experience has been, in general, that relatively scanty if any accurate data are available with reference to tributary populations and that operators are less sure of this factor than the others. Too much emphasis cannot be placed, however, on the care exercised in obtaining a representative sample for analysis and on the care exercised in the laboratory determination of the five-day B.O.D. Particularly for larger plants, sewage flows are obtained by positive measurement and probably are accurate within satisfactory limits.

* Presented before the Tenth Annual Ohio Conference on Sewage Treatment, Columbus, Ohio, Oct. 2, 1936. Reprinted from the Proceedings.

Although in our work in the State Department of Health we have frequently utilized the per capita oxygen requirement figures, or an estimated value, it has only been within the last two years that a concerted effort has been made to collect such data generally from our sewage plant operators. Flow data and B.O.D. values have been and are available on the monthly reports of operation submitted to the department, but it has been necessary to look to the operators for the tributary population figures. Hence it has been only with their assistance that the data so far collected are available.

In Table I those municipalities from which data have been obtained have been classified into (*a*) municipalities, at which sewage works serve over 5,000 people and (*b*) municipalities, at which sewage works serve less than 5,000 people; the primary reason being that the larger works in general have better facilities and are better prepared to obtain continuous, accurate data. The average per capita per day oxygen required (five-day B.O.D.) in pounds has been shown, where plants have been continuously in service, for the five years 1931 to 1935 inclusive, together with the average values for the five-year period or for the period in service. Further, for purposes of classification the yearly average figures of population, of sewage flow in million gallons per day, and of five-day B.O.D., together with the respective period averages are shown. Also the table contains the average per capita per day sewage flow.

Reference to the table will indicate that in instances the per capita per day oxygen requirement values are fairly constant, or show definite trends. In other instances they are less regular, reflecting periodical influences, or should this not be the case, inaccuracies in the factors involved in the calculation. Attention is called to the average per capita per day oxygen requirement value (0.115 lbs.) of the sewage from a relatively small residential area of Portsmouth. This primarily is domestic sewage collected by a sanitary sewerage system. The Cleveland Westerly sewage values reflect a consistently heavy industrial load, particularly during the years 1932 to 1935 inclusive. The values of the sewage for the village of Medina indicate such influences, but further indicate that they have occurred irregularly. The industrial waste in the village comprises primarily a pickle canning waste, although an ice cream factory has an influence. The pickle plant contributes perhaps 30 to 33 per cent of the municipal sewage by volume. It will be noted that the per capita sewage flow for the city is low and that the normal sewage will be concentrated. The high oxygen demand, however, is caused by the industrial load. It is interesting to note that the average value for the sewage at Delaware, one which is concentrated and primarily domestic in character, is comparable to the value for the Dayton sewage and for others which probably are more nearly of average concentration as far as Ohio municipalities are concerned. In the case of Columbus it may be said that, at present, measurements of the total flows cannot be obtained and the flow figures in the table are estimated values. C. D. McGuire, Chemist-in-Charge of the

TABLE I.—*Data Pertinent to Oxygen Requirement of Sewage of Ohio Municipalities*

| Municipalities Sewage Works Serving Over 5,000 | Type Sewerage | Tributary Population, Thousands of People | | | | | | Average Flow, Million Gallons Daily | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1931 | 1932 | 1933 | 1934 | 1935 | Av. for Period | 1931 | 1932 | 1933 | 1934 | 1935 | Av. for Period |
| Akron | C-S | 202 | 202 | 196 | 207 | 213 | 204 | 28.1 | 31.2 | 31.4 | 27.7 | 29.6 | 29.6 |
| Alliance | S | 22.6 | 22.4 | 22.2 | 22.4 | 22.6 | 22.4 | 2.22 | 2.06 | 1.93 | 1.87 | 2.10 | 2.04 |
| Canton | S | 100 | 103 | 104 | 104 | 104 | 103 | 9.3 | 10.3 | 9.8 | 9.5 | 10.7 | 9.92 |
| Cleveland | | | | | | | | | | | | | |
| Southerly | C | 130 | 225 | 225 | 225 | 225 | 206 | 11.9 | 20.4 | 20.1 | 20.4 | 20.2 | 18.6 |
| Westerly | C | 217 | 217 | 217 | 210 | 210 | 214 | 29.2 | 30.0 | 28.5 | 26.9 | 29.0 | 28.7 |
| Easterly | C | 534 | 549 | 563 | 575 | 588 | 562 | 88.0 | 84.4 | 82.5 | 79.1 | 78.6 | 82.5 |
| Columbus | C | 297 | 300 | 305 | 312 | 317 | 306 | 32.3* | 31.5* | 31.8* | 34.0* | 33.2* | 32.6 |
| Dayton | C-S | 221 | 224 | 228 | 231 | 235 | 229 | 21.3 | 22.1 | 21.7 | 19.4 | 22.4 | 21.4 |
| Delaware | S | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | .404 | .380 | .345 | .345 | .373 | .371 |
| Elyria | C-S | 23.4 | 22.9 | 22.4 | 21.4 | 21.9 | 22.4 | 2.06 | 2.34 | 2.42 | 1.98 | 2.30 | 2.22 |
| Findlay | C-S | | | 16.4 | 17.2 | 17.4 | 17.0 | | | 1.9 | 1.7 | 1.6 | 1.73 |
| Fostoria | C | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 11.5 | 1.58 | 1.66 | 1.63 | 1.28 | 1.35 | 1.50 |
| Lima | C | | | 40.4 | 40.6 | 40.7 | 40.6 | | | 5.55 | 4.86 | 4.74 | 5.05 |
| Marion | S | 23.3 | 23.3 | 23.3 | 23.3 | 23.3 | 23.3 | 1.46 | 1.54 | 1.53 | 1.10 | 1.21 | 1.37 |
| Norwalk | S | | | 7.8 | 7.8 | 7.8 | 7.8 | | | .776† | .601 | .682 | .686 |
| Toledo | C-S | | 249‡ | 255 | 276 | 273 | 263 | | 23.2‡ | 26.8 | 26.0 | 26.1 | 25.5 |
| Sewage Works Serving Under 5,000 | | | | | | | | | | | | | |
| Delphos | C | | 3.52 | 3.52 | | 3.52 | 3.52 | | .478 | .527 | | .362 | .456 |
| Madison | S | | .850 | .875 | .900 | .900 | .881 | | .147 | .169 | .160 | .187 | .166 |
| Medina | S | | | 4.1 | 4.1 | 4.1 | 4.1 | | | .182‡ | .206 | .267 | .218 |
| Oxford | S | 4.30 | 4.27 | 4.21 | 4.41 | 4.62 | 4.36 | .380 | .509 | .588 | .572 | .382 | .486 |
| Portsmouth (Sciotoville) | S | | 2.0 | 2.0 | 2.0 | 2.1 | 2.02 | | .171 | .164 | .138 | .145 | .154 |

C-S—Combined and Sanitary Sewers.
C—Combined Sewers.

* Flows estimated.
S—Sanitary Sewers

† 9 Months data—not in average.
‡ 6 Months data—not in average.

TABLE I.—*Continued*

| Municipalities | Average Flow for Period gpcd. | Average B.O.D. Parts per Million | | | | | | Oxygen Required (5 Day B.O.D.) in Pounds per Capita per Day | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sewage Works Serving Over 5,000 | | 1931 | 1932 | 1933 | 1934 | 1935 | Av. for Period | 1931 | 1932 | 1933 | 1934 | 1935 | Av. for Period |
| Akron | 145 | 150 | 137 | 153 | 188 | 173 | 160 | 0.173 | 0.174 | 0.194 | 0.206 | 0.199 | 0.189 |
| Alliance | 91 | 199 | 232 | 236 | 267 | 214 | 230 | 0.163 | 0.177 | 0.171 | 0.186 | 0.163 | 0.172 |
| Canton | 96 | 182 | 188 | 207 | 246 | 202 | 205 | 0.142 | 0.153 | 0.159 | 0.185 | 0.172 | 0.162 |
| Cleveland | | | | | | | | | | | | | |
| Southerly | 90 | 153 | 190 | 259 | 255 | 191 | 210 | 0.117 | 0.140 | 0.193 | 0.196 | 0.142 | 0.158 |
| Westerly | 134 | 138 | 219 | 213 | 235 | 195 | 200 | 0.152 | 0.250 | 0.228 | 0.250 | 0.224 | 0.221 |
| Easterly | 147 | 147 | 162 | 132 | 140 | 135 | 143 | 0.205 | 0.208 | 0.159 | 0.160 | 0.149 | 0.176 |
| Columbus | 107 | 180 | 194 | 169 | 181 | 180 | 181 | 0.163 | 0.170 | 0.147 | 0.164 | 0.157 | 0.160 |
| Dayton | 93 | 199 | 181 | 138‡ | 181 | 172 | 183 | 0.159 | 0.147 | 0.105‡ | 0.127 | 0.137 | 0.142 |
| Delaware | 46 | 341 | 341 | 358 | 386 | 416 | 368 | 0.144 | 0.135 | 0.129 | 0.142 | 0.162 | 0.142 |
| Elyria | 99 | 214 | 226 | 185 | 227 | 218 | 214 | 0.156 | 0.192 | 0.167 | 0.175 | 0.192 | 0.176 |
| Findlay | 102 | | | 155 | 199 | 172 | 175 | | | 0.154 | 0.175 | 0.116 | 0.148 |
| Fostoria | 130 | 194 | 213 | 157 | 192 | 181 | 187 | 0.202 | 0.256 | 0.185 | 0.181 | 0.177 | 0.204 |
| Lima | 124 | | | 172 | 233 | 208 | 204 | | | 0.197 | 0.232 | 0.202 | 0.210 |
| Marion | 59 | 294 | 262 | 278 | 381 | 365 | 316 | 0.154 | 0.145 | 0.153 | 0.150 | 0.158 | 0.152 |
| Norwalk | 88 | | | 171† | 250 | 239 | 220 | | | 0.142† | 0.174 | 0.172 | 0.173 |
| Toledo | 97 | | 168§ | 185 | 224 | 212 | 197 | | 0.128† | 0.152 | 0.170 | 0.169 | 0.164 |
| | | | | | | | | Average | | | | | 0.172 |
| Sewage Works Serving Under 5,000 | | | | | | | | | | | | | |
| Delphos | 130 | | 119 | 96 | | 147 | 121 | | 0.135 | 0.120 | | 0.126 | 0.127 |
| Madison | 188 | | 108 | 130 | 114 | 121 | 118 | | 0.156 | 0.209 | 0.169 | 0.209 | 0.186 |
| Medina | 53 | | | 689§ | 717 | 304 | 570 | | | 0.255§ | 0.300 | 0.165 | 0.233 |
| Oxford | 111 | 140 | 139 | 103 | 162 | 169 | 143 | 0.103 | 0.137 | 0.120 | 0.174 | 0.116 | 0.130 |
| Portsmouth | 76 | | 196 | 162 | 191 | 182 | 183 | | 0.139 | 0.107 | 0.109 | 0.104 | 0.115 |
| | | | | | | | | Average | | | | | 0.158 |
| | | | | | | | | Av. per capita per day 5 day oxygen demand | | | | | 0.169 |

* Flows estimated. † 9 Months data—not in average.

‡ 6 Months data—not in average.

§ Omitted from average because of known error in sampling.

Columbus sewage treatment plant, has stated that probably a more representative figure would result if a per capita daily sewage flow of 125 gallons and an average five-day B.O.D. of 181 ppm. were used, which would result in a per capita per day requirement of 0.19 lbs. The average per capita per day oxygen requirement (five-day B.O.D.) for the first group of municipalities which have sewage works serving over 5,000 people is 0.172 lbs.; for those in the second group serving less than 5,000, 0.158 lbs.; for the twenty-one municipal sewages considered at this time 0.169 lbs. These averages may be taken for what they are worth. At least a comparison is afforded as far as these sewages are concerned. It may be interesting to know that the total pounds of oxygen demand per capita per day used by the Engineering Board of Review of the Sanitary District of Chicago, published in Part 3, Pages 69 to 75 inclusive of the report under date of February 21, 1925, was 0.24 lbs. Using .68, the conversion number of the Phelps Stability Curve, the five-day per capita demand of 0.163 lbs. is obtained from the above value of total demand. This is offered as a comparison to the average for the Ohio sewages herewith considered.

TABLE II.—*Oxygen Requirements of Sewage by Months, Norwalk*

| Month | 1934 Population 7,800 | | | 1935 Population 7,800 | | |
|---|---|---|---|---|---|---|
| | Flow Av. mgd. | B.O.D. 5 day 20°C. ppm. | $O_2$ Req. lbs. p.c.d. | Flow Av. mgd. | B.O.D. 5 day 20°C. ppm. | $O_2$ Req. lbs. p.c.d. |
| January | 0.668 | 214. | 0.152 | 0.639 | 245. | 0.167 |
| February | 0.521 | 276. | 0.154 | 0.751 | 247. | 0.198 |
| March | 0.919 | 182. | 0.179 | 0.951 | 165. | 0.167 |
| April | 1.270 | 124. | 0.169 | 0.659 | 269. | 0.189 |
| May | 0.674 | 271. | 0.195 | 1.093 | 151. | 0.176 |
| June | 0.589 | 245. | 0.154 | 0.651 | 195. | 0.136 |
| July | 0.585 | 181. | 0.113 | 0.614 | 187. | 0.122 |
| August | 0.601 | 312. | 0.199* | 0.734 | 328. | 0.256* |
| September | 0.615 | 318. | 0.209* | 0.555 | 355. | 0.210* |
| October | 0.479 | 295. | 0.151 | 0.446 | 265. | 0.126 |
| November | 0.451 | 301. | 0.141 | 0.525 | 226. | 0.127 |
| December | 0.494 | 288. | 0.152 | 0.570 | 239. | 0.146 |

* Corn Wastes.

In Table II is given the per capita per day oxygen requirement of the Norwalk sewage by months for the years 1934 and 1935, together with the data from which these values are determined. Although other examples may be given, the fluctuations in these values for Norwalk during the respective years reflect very definitely known industrial waste loads. The higher values during the spring months are due to milk wastes tributary to the sewerage system. A milk flush season occurs usually during this period. The high values in August and September can definitely be attributed to corn canning wastes. In

contrast to this, Table III presents like data by months for Toledo sewage for the years 1934 and 1935, during which the values of the per capita per day oxygen requirements appear to be fairly constant.

TABLE III.—*Oxygen Requirement of Sewage by Months, Toledo*

| Month | 1934 Population 276,000 | | | 1935 Population 273,000 | | |
|---|---|---|---|---|---|---|
| | Flow Av. mgd. | B.O.D. 5 day 20°C. ppm. | $O_2$ Req. 5 day lbs. p.c.d. | Flow Av. mgd. | B.O.D. 5 day 20°C. ppm. | $O_2$ Req. 5 day lbs. p.c.d. |
| January | 24.29 | 238. | 0.175 | 26.26 | 243. | 0.194 |
| February | 23.57 | 240. | 0.171 | 25.41 | 235. | 0.182 |
| March | 29.57 | 186. | 0.166 | 28.35 | 191. | 0.165 |
| April | 42.84 | 118. | 0.153 | 27.68 | 231. | 0.195 |
| May | 27.64 | 244. | 0.204 | 29.83 | 180. | 0.164 |
| June | 25.29 | 244. | 0.186 | 22.61 | 195. | 0.135 |
| July | 25.74 | 217. | 0.165 | 25.49 | 199. | 0.155 |
| August | 25.29 | 231. | 0.177 | 28.46 | 161. | 0.140 |
| September | 23.67 | 229. | 0.164 | 25.61 | 212. | 0.166 |
| October | 20.76 | 248. | 0.155 | 23.94 | 220. | 0.161 |
| November | 21.11 | 253. | 0.161 | 25.53 | 231. | 0.180 |
| December | 22.86 | 237. | 0.164 | 24.48 | 249. | 0.186 |

Although available data are restricted to a relatively few of the total Ohio municipalities which have sewage treatment works, it is believed that they reflect fairly representative conditions throughout the state. The per capita oxygen demand figure should give valuable information both in the design of sewage works and in their operation. It should be particularly useful when extensions to plant are to be made; it serves a particularly useful purpose in determining the population equivalents of industrial wastes; and it further assists materially in studying the effect of sewage on the receiving body of water. The value of this figure is sufficient to warrant such additional effort on the part of the operators to obtain the factors, pertinent for computation, to sufficient occuracy that confidence may be had in the per capita per day oxygen requirement of the sewage of their respective municipalities.

# NOTES ON OPERATION OF THE SAN ANTONIO ACTIVATED SLUDGE PLANT *

By E. J. M. Berg

*Chemist, San Antonia Sewage Treatment Plant*

In a paper read before this body January 16th, 1933, W. S. Stanley, Superintendent of the San Antonio Sewage Treatment Plant, calculated that the needed digester capacity for this plant was 8,225,000 gallons. This figure was based on the amount and consistency of the sludges, primary, activated and digested, which have been obtained at this plant during two years of operation, and the failure of the primary settling tanks to settle properly the solids delivered to them in the form of excess activated sludge. In other words, this digester capacity was based on the fact that, with the existing equipment, the excess activated sludge must be delivered to the digesters directly and can not be thickened and pumped to the digesters with the primary sludge. This capacity of 8,225,000 gallons was then computed by calculations based on performance of the plant during two years.

A number of experimental digesters were set up for tests on a laboratory scale. Of course, the results obtained by laboratory experiments can not be expected to be duplicated in plant performance, but correctly interpreted, they indicate probabilities.

## Experimental Digestion Studies

The digester used was made of a 5 gallon glass bottle, inverted in a rack. Three ½ in. holes were drilled in the flat bottom, which was now the top of the digester, one for a thermometer, one for a gas delivery pipe, and one for a feed pipe. Four similar holes were drilled along the side and fitted with valves so that the supernatant could be drained off at the most suitable point. The neck of the bottle, which was now the bottom, was fitted with a valve for withdrawal of the digested sludge. The amount of sludge fed daily was proportioned to the actual plant digester space of 3,320,000 gallons and the amount of sludge actually produced by the plant. The amount of digested sludge drawn was based on the amount of ash entering the digester daily; the ash drawn should be equal to the ash fed. This necessitated a daily analysis of everything entering and leaving the digester. As the volume entering the digester daily was larger than the volume leaving it, there was a certain volume of supernatant to be disposed of. This suggested the following method of feeding: first the proper amount of supernatant was drawn at the level which would cause the least disturbance inside the digester; then the proper amount of digested sludge was drawn; then the new sludge was added.

* Presented before the Nineteenth Texas Water Works Short School, College Station, Texas, Feb. 20, 1937. Reprinted from the Proceedings.

*Activated Sludge.*—The first experiment was made using excess activated sludge only. The digester was started with 3.0 litres of digested sludge, with 4.31% total solids, 38.2% ash, and a pH of 7.1. The daily amount of activated sludge added (2.0 l.) gave an actual digestion period of 39 days, only ⅔ of the time found necessary by experience. If the proper amount of primary sludge had been added, the time would have been reduced still more. Digestion proceeded without much disturbance inside the digester; the supernatant was very clear; there was only one day when feeding had to be omitted because of heavy supernatant. There was practically no scum. The pH, however, dropped from 7.1, to 6.7 at the end of the experiment 60 days later. This is good evidence of overloading. The average composition of the material entering or leaving the digester was:

| | Total Solids | Ash |
|---|---|---|
| Activated sludge fed | 0.60% | 25.3% |
| Digested sludge drawn | 1.59% | 29.0% |
| Supernatant drawn | 0.15% | 25.4% |

These figures also show that, as was expected, there was not sufficient digestion capacity. The large volume of sludge added necessitated withdrawal of an almost equal amount of sludge and supernatant. This decreased the detention time and resulted in a poorly digested and thin sludge. Such a thin sludge necessitates a large number of drying beds, and the sludge, when dry, will leave only a thin crust, which when removed will carry with it a large amount of sand. The experiment showed that our digestion space was entirely inadequate for digestion of the excess activated sludge.

*Primary Sludge.*—It was next decided to make an experiment using primary sludge alone, and to determine how much primary sludge the plant, theoretically, should be able to handle. The digester was started with 18 l. of ripe sludge, total solids 5.40%, ash 38.9%, and pH 6.9. The feeding rate of 1.0 l. of primary sludge per day was based on average plant production of 46,500 gallons per day. The first digested sludge was drawn after 6 days, this making a detention period of 22 days. The sludge had compacted considerably at that time, the first sample showing 7.81% solids as against 5.40% at the begining. Digestion progressed properly. The supernatant suspended solids averaged only 116 p.p.m. The pH went up to 7.05. There was occasional foaming, which would rarely last more than an hour. This was always followed by a satisfactory separation of liquids and solids.

After 70 days, the feeding rate was increased to 1.5 l. per day, corresponding to a plant production of 70,000 gallons of primary sludge per day. Digestion progressed properly, as shown by a clean supernatant and an increasing pH. The total solids in the ripe sludge dropped from the average of 8.39% during the first period to 6.08% during the second period. This thinning was probably caused by more frequent turning-over of the digester, but this turning-over was never prolonged and it was always followed by satisfactory settling of the

solids. The average supernatant suspended solids was 151 p.p.m. There was the beginning of scum formation.

After two weeks the feeding rate was raised to 2.0 l. per day for 3 weeks. This corresponds to a plant production of 93,000 gallons of primary sludge per day. The digested sludge concentration rose to 7.00%; the suspended solids in the supernatant dropped to 93 p.p.m.; the pH rose to 7.3. The amount of scum increased.

The feeding rate was now raised to 3.0 l. per day. The suspended solids in the supernatant rose rapidly to 385 p.p.m. There was a great increase in the agitation in the digester, and most of the solids inside the digester rose to the scum-line. After a few days there was so little digested sludge at the bottom of the digester that, on drawing the required amount of digested sludge, the supernatant broke through. It became impossible to draw the required amount of digested sludge. The contents of the digester were stirred, in an attempt to break up the heavy scum layer, but most of the solids rose to the top. After two weeks, all the contents of the bottle were thoroughly stirred. Very soon we again had a very heavy scum layer and a thin layer of solids at the bottom, making it impossible to draw the proper amount of digested sludge without drawing a large amount of supernatant. Evidently the 2.0 l. per day feeding rate represents the highest amount our digesters can handle without overloading (93,000 gallons per day).

During the period of feeding 2.0 l. daily the average composition of the sludges added or drawn was:

| | Total Solids | Ash |
|---|---|---|
| Primary sludge | 4.58% | 22.3% |
| Digested sludge | 7.00% | 42.9% |
| Supernatant | 0.21% | 39.6% |

These figures lead us to believe that our four original digesters having a capacity of 3,344,000 gallons, can well handle all of our primary sludge, giving a fairly heavy, well digested sludge and a good supernatant, provided the digesters are not thrown out of balance by giving them an additional load of activated sludge.

*Mixed Sludges.*—It was now decided to make an experiment in digesting both primary and activated sludge, based on plant production of both sludges and a theoretical digester capacity of 8,225,000 gallons, and starting without any digested sludge. A large bottle holding 42 l. was used, arranged as has been described before. This bottle was placed inside a cabinet so as to prevent the formation of algae and simulate as much as possible the conditions in an underground and closed digester. This also enabled us to control the temperature by means of a covered electric light placed inside the cabinet. The gas collecting and storage bottles were placed on the outside.

The most significant facts about the progress of digestion were these: There was very little foaming and scum formation. The contents of the digester turned over quite frequently, perhaps every other day. The solids would then be distributed throughout the digester,

but within half an hour or an hour at the most, there would be a complete separation of solids and liquid. The digester was kept in operation for 15 weeks, and during that time no feeding period was missed or delayed for more than an hour because of heavy supernatant. This turning over provided the stirring needed to mix the incoming sludge with the sludge already in the digester. I find in the notes on the progress of the digester the following notations:

| Date | Liters of Scum |
|---|---|
| September 10 | 4.0 |
| September 14 | 4.7 |
| September 24 | 4.2 |
| October 4 | 2.2 |
| October 8 | 3.0 |
| October 25 | 1.0 |
| November 9 | 1.5 |
| November 28 | 1.0 |

The amount of scum decreased as digestion progressed, and when the digester was emptied there were only traces of scum. Another very interesting fact was the low amount of suspended solids in the supernatant. The average suspended solids was 200 p.p.m.; the lowest was 36 p.p.m., the highest 1456; the B.O.D., two tests only, was 190 p.p.m.

The average composition of the sludges was as follows:

| | Total Solids | Ash | pH |
|---|---|---|---|
| Activated sludge | 0.46% | 23.7% | 7.0 |
| Primary sludge | 4.71% | 21.2% | 6.7 |
| Digested sludge | 2.96% | 31.4% | 6.9 |
| Supernatant | 0.12% | 48.3% | 6.9 |

The gas produced amounted to 13.3 cu. ft. per lb. of volatile matter digested.

### Conclusions, Digestion Experiments

The following conclusions were drawn from the three experiments made:

(1) Our four original digesters, having a volume of 3,344,000 gallons, are not large enough to digest excess activated sludge, even without primary sludge. Digestion of activated sludge alone produces a very thin sludge that is wasteful of drying beds.

(2) The four original digesters can handle all the primary sludge. But digestion of primary sludge alone tends to produce large amounts of scum that seem to be impossible to be broken up and removed from the digester. Unless the drawoff pipe for removing supernatant is properly placed, the large amount of heavy scum will clog it and cause a heavy supernatant or entirely prevent the flow of supernatant.

(3) If sufficient digester space is provided, 5.5 cu. ft. per capita, or 40 cu. ft. per lb of volatile matter added per day, digestion of a mixture of activated and primary sludge will proceed with a minimum of disturbance in the digesters, giving a good supernatant but a very thin digested sludge. Whether it is possible to thicken this sludge by longer

detention is questionable; a dead sludge that will not dry readily may result.

(4) The natural activity in the digester is sufficient to give the amount of stirring needed for intimate mixing of the incoming with the digesting sludge.

### Installation of Additional Digesters

Our present digester space, including the six new digesters just completed, is 8,944,000 gallons. These new digesters were built according to the plans made by Mr. W. S. Stanley. They are 75 ft. in diameter, 26 ft. deep at the sides, and 32 ft. deep in the center. The pipe for drawing the digested sludge runs inside the digester from a sump 1 ft. deep in the center. The incoming sludge line extends to the center of the tank, 10 ft. above the bottom. There are three outlets 6 in. in diameter for drawing the supernatant. These are 14 ft., 18 ft., and 27 ft. from the bottom of the tank, respectively. These three outlets are connected to a manifold, and by opening the proper valve, supernatant can be drawn from either one of these levels. Two 500 gals. per min. pumps have been provided; one for drawing supernatant and one for the digested sludge.

These tanks have been put in operation the first week in February, 1937. Each one is being seeded with ripe sludge from the old digesters, which is pumped into them instead of to the drying beds. They also receive all of the primary and excess activated sludge. While the excess sludge is being pumped in through the line 10 ft. from the bottom, the supernatant is drawn from the outlet 18 ft. above the bottom. As yet the supernatant has about 480 p.p.m. (three tests) suspended solids and a B.O.D. of 290 p.p.m. (one test). This supernatant is decidedly acid. But as we expect to introduce more digested sludge, it should improve.

### Operation of Activated Sludge Plant

Next to insufficient digester space, bulking of activated sludge has been one of our major troubles. Much has been written about the causes of sludge bulking, and many remedies have been suggested. According to our experience, there is only one cause, insufficient air; and one remedy, more air. One may try chlorine or lime, or any other remedy, but it seems to me that in a sewage plant that uses air for purification of sewage, air should be the remedy employed as a cure for a sickness caused by lack of air.

When the San Antonio Sewage Treatment Plant was first started, our budget permitted us to use two air compressors whenever necessary. The amount of air used averaged as high as 1.28 cu. ft., and never less than 1.00 cu. ft., per gal. of sewage. We had a rapidly settling sludge, a wonderful effluent very low in suspended solids and ammonia, and high in nitrate. When our budget was cut so that we could use only one compressor, giving only .80 to .90 cu. ft. of air per gal. of

sewage, our troubles began. And when overloaded digesters began to pour foul supernatant into the primary clarifiers, our sludge began to bulk and the bulking persisted.

Consider these figures:

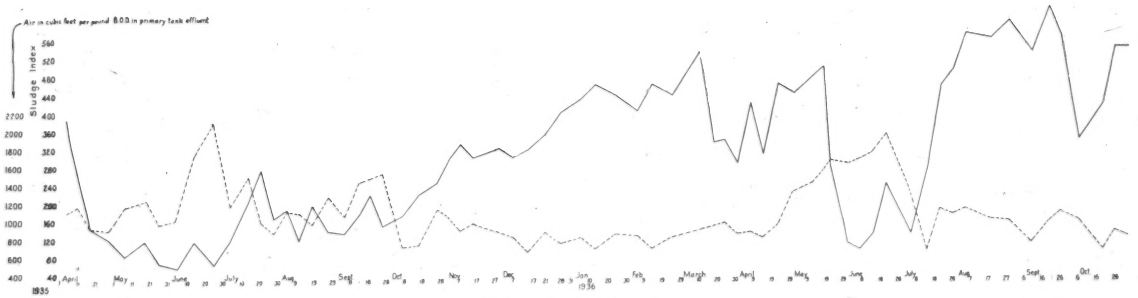
| Date | Air in Cu. Ft. per Gal. Sewage | Sludge Index |
|---|---|---|
| Jan. 1932 | 1.23 | 93 |
| Feb. 1932 | 1.15 | 136 |
| Mar. 1932 | 1.05 | 249 |
| April 1932 | .72 | 394 |
| May 1932 | .82 | 310 |
| June 1932 | .86 | 291 |
| June 1936 | 1.26 | 167 |

Still, this evidence is not conclusive. The term "air in cubic feet per gallon of sewage" is not a good measure of aeration tank operation. It does not take into account the character of the sewage or of the digester overflow; nor does it consider the amount of solids carried in the aeration tanks. The search for a measure that would really show the amount of work imposed on the plant and its relation to the air used, brought about the adoption of the term "air in cubic feet per pound of B.O.D. load in the primary effluent." As we are dealing with settleability, the sludge index, defined by Dr. Mohlman of the Chicago Sanitary District as the per cent of aeration tank sludge settling in 30 minutes, divided by the per cent suspended solids, seems a very good measure.

In April, 1935, we passed out of a period of bulking. Beginning with April 5th I calculated the sludge index and the air in cu. ft. per lb. of primary effluent B.O.D. load for each day on which a B.O.D. was made. That meant three such calculations per week. The averages of three calculations were then plotted, one curve showing the variations of the sludge index, the other the variations of the cu. ft. of air per lb. of B.O.D. load. The reciprocal correspondence of the two curves is quite striking. An increase in air per lb. of B.O.D. load results in a decrease in the sludge index.

Of course it is impossible to cure a long standing case of bulking in a few days by giving more air. From November 1, 1935, till May, 1936, the sludge index had been above 300. Most of the time it had been above 400, going up to 530 at one time. During that time we were giving about 800 cu. ft. of air per lb. of B.O.D. On May 6 we began using two blowers and the amount of air rose to 1560 cu. ft. per lb. of B.O.D., when the sludge index dropped abruptly from about 500 on May 17, to 100 on June 7. On that day the amount of air given was 1720 cu. ft. per lb. of B.O.D. of primary effluent. In the latter part of June we discontinued the use of two compressors. About July 13 the amount of air had dropped to 680 cu. ft. per lb. of B.O.D., and the sludge index had risen to about 580.

I draw the following conclusions, at least so far as our plant is concerned, from this study: An increased load put on the plant, be it from




EXPLANATION OF CHART.

The solid-line curve indicates the sludge index, which is determined as follows:

For example if the per cent settling of the sludge in the aeration tanks after 30 minutes sedimentation is 30%; and the same sludge has 1500 p.p.m. or .15% suspended solids by weight then 30% divided by .15% equals 200, the sludge index.

The broken-line curve indicates the cubic feet of air per pound B.O.D. in the primary tank effluent, which is determined as follows:

Given: Sewage flow, 18,000,000 gallons per day; B.O.D. of the primary tank effluent, 120 p.p.m.; air, 15,000,000 cubic feet per day.

Then, 18,000,000 multiplied by 8.33 multiplied by 120 divided by 1,000,000 equals 18,000 pounds B.O.D. load. 15,000,000 divided by 18,000 equals 633.3, cubic feet of air per pound B.O.D.

an increase of solids through sudden flushing of the sewers, or from trade wastes of any kind, will increase the B.O.D. load of the primary effluent. This then requires more air for treatment. It may need more return sludge for more complete seeding; but more sludge in the aeration tanks demands more air. If this air is not provided, the sludge will gradually begin to bulk. It will first fail to settle, and, if the lack of air extends over a long time, it will become slimy and malodorous. The algae on the final clarifiers, instead of being green in color, will become a pale gray.

To correct such a case of bulking takes air, much air, given over a long time, maybe two weeks. It must be borne in mind that all the sludge in the system has become foul, sick, under-oxidized, and all this foul sludge must be revived, and all this excess of volatile matter must be oxidized. If bacteria or protozoa take a part in the purification process, it is easy to see that the organisms living in a healthy sludge will die out in a diseased sludge. Only as the sludge is brought back to normal can these organisms reappear and help in promoting oxidation and nitrification. I say that much air is needed to recondition the sludge; it must be borne in mind that, as the air passes through the sludge, only a small proportion can be utilized. Hence it is possible to waste air. A larger amount of returned sludge, if the proper amount of air can be given, would hasten the reconditioning of the plant. A rapid and accurate method of determining the dissolved oxygen in the mixed liquor should be of great help. In San Antonio, 1000 cu. ft. of air per lb. of primary effluent B.O.D. seems to be the minimum that will keep a good sludge in proper condition.

ACKNOWLEDGMENT

These experiments were made under the supervision of Mr. W. S. Stanley, Superintendent of the San Antonio Sewage Plant. This plant is under the jurisdiction of Hon. Paul E. Steffler, Commissioner of Streets and Public Improvements.

# OPERATING THE EL PASO CHEMICAL TREATMENT PLANT *

By Chas. D. Yaffe

*Supt., Sewage Treatment Plant, El Paso, Texas*

One year ago the City of El Paso put into operation its newly remodeled sewage treatment plant. This plant employs chemical precipitation as an aid in treatment, and as it is the first large plant in the state to use this type of treatment, the results obtained may prove of interest.

## Sewage Flow and Dilution Ratios

El Paso is a city of approximately 100,000 population. It is located on the Rio Grande in the extreme west portion of the state. The climate there is quite dry, the average annual rainfall being under ten inches. The flow of water in the river is controlled to a large extent by the Elephant Butte dam, situated 115 miles above El Paso. This water is used for irrigation purposes in the valley, both above and below the city. Water is released from the dam between the months of March and November and farmers are allowed a fixed amount per acre dependent upon the supply available. During the winter months very little water is released through the dam and a reserve is built up. Consequently, the river flow at El Paso is small during this period. Average flow during the irrigation season is about 900 cu. ft. per second, and during the winter it is around 200 cu. ft.

This results in a somewhat different situation than is encountered in many other localities where the summer season is the period of low flow. Usually the hot weather season is the one in which the problems of odors, oxidation and nuisances are most difficult. As we have a larger volume of dilution water during this period, our problem is somewhat simplified. However, this is also the time of the year that the water in the river is used for irrigation purposes. Some of the water goes to irrigate truck farms located below the city. This, briefly, is an outline of the problem encountered.

We might mention at this point that during the past year we have made several dissolved oxygen determinations each month along the river. The average amount of dissolved oxygen above the plant outfall has been 6.2 p.p.m. A number of determinations between half a mile and 2.5 miles downstream gave an average of 5.0 p.p.m., at an average distance of 2 miles. Determinations from 4 to 10 miles downstream showed 5.6 p.p.m., at an average distance of 6 miles. Water is taken out of the river for irrigation purposes approximately 11 miles below the outfall.

Sewage flow in El Paso averages approximately 6,000,000 gallons per day. While water consumption during the summer increases tre-

* Presented before the Nineteenth Texas Water Works Short School, College Station, Texas, Feb. 19, 1937. Reprinted from the Proceedings.

mendously, sewage flow shows a much smaller increase. This is due to the use of much of the water for sprinkling lawns.

The sewage reaches the plant through three lines. Thirty-five to forty per cent comes by gravity through an inverted syphon 7200 feet long. About five per cent comes from the new Val Verde pump station located about one-fourth mile east of the plant. The remainder flows by gravity to the main pumping plant one-half mile north of the treatment plant and is pumped from there. At this pumping station there is one 4000 g.p.m. pump and one 2000 g.p.m. pump. These are used separately or together, depending on the rate of flow, and are of sufficient capacity for the normal flow. There is, in addition, a 6000 g.p.m. pump which is used when flows are exceptionally large. This pump can be driven by a gasoline engine in case of power failure. We have had occasion to use it a number of times during the past two years. The electric company has had labor difficulties for two years, and interruptions in service due to sawed down power poles, etc., have been far too frequent occurrences. Such trouble usually comes at the most inconvenient hours and when the weather is most disagreeable.

## Description of Plant

The treatment plant as originally built in 1922 consisted of fifteen sedimentation tanks, each 75 ft. long by 41 ft. wide and 11 ft. deep. Sewage was run through a tank until a certain amount of sludge had accumulated. Then the tank was cut off and the sludge allowed to digest from one to three months. The sludge was then run out on drying beds.

The tanks were built in two rows with the raw sewage entering through a conduit between the two rows. There were nine tanks on one side and six on the other. The effluent ran by gravity to the river which was about one-fourth mile south of the plant. The river channel was straightened a year or so ago under the river rectification program, and the new channel is approximately one-half mile from the plant.

The city obtained a PWA loan of $400,000 for sewer extensions and remodeling the treatment plant. This money is being repaid through a sewer service charge of 25c per month for each residence. Other customers pay in proportion to the quantity of water consumed.

The remodeled treatment plant, designed by Black and Veatch, was put into operation February 1, 1936.

The incoming sewage passes first through two 24-inch Chicago Pump Co. comminutors. It then passes through two grit chambers. The comminutors and grit chambers are operated in parallel sets. Grit is scraped up by Link Belt collectors, washed by a dewatering screw, and discharged into a hopper. It is removed daily and disposed of on the city dump, located near the plant. Grit collected averages about 0.5 cu. yd. daily. The grit chambers are 3 ft. wide, 4.5 ft. deep and 45 ft. long.

From the grit chambers the sewage enters a pre-aeration tank where the chemicals are added and mixed. Air is furnished by two Root-Con-

nersville blowers, each having a capacity of 100 cu. ft. per minute. It is distributed through 55 filtros plates. The bottom of the tank is of the ridge-and-furrow type. There are 11 rows, each with 5 plates. The tank is 18 ft. long, 69 ft. wide, and 12 ft. deep. The mixing period is from 10 to 15 minutes.

The sewage then enters a sedimentation tank 126 ft. long, 75 ft. wide, and 10 ft. deep. The detention period is from 1.5 to 2 hours. Sludge is removed continuously by four Link Belt collectors operating in parallel. These also skim the grease from the liquid surface into a grease trap. A cross collector brings the sludge to a sump in one corner of the sedimentation tank and it is pumped from there to the sludge digestion tanks.

The effluent from the sedimentation tank passes over a notched weir into a trough and then into a conduit. This leads to a venturi meter and from there it enters the outfall line running to the river. Provisions are made whereby the effluent can be chlorinated. The sedimentation tank was made from three of the old tanks on the side which formerly had six. The other three were left unchanged and can be used for partial treatment, should the rest of the plant have to be shut down for a period of time.

## Sludge Digestion

The nine tanks on the other side were converted into sludge digesters. The sludge is pumped to the first tank and then passes in series through the nine tanks. These tanks are each 75 by 41 ft. and 11 ft. deep.

The first three tanks are covered and equipped for gas collection. These tanks are heated when necessary by hot water lines which are placed along the walls. This water is circulated through a gas heated boiler. The sludge is held at about 85° F. The gas produced is being used in the boiler and for heating and laboratory purposes. The excess is burned in a waste burner. We are now investigating the possibility of utilizing this excess for power purposes.

As originally set up the gas meter measured the gas used. This amounts to about 10,000 cu. ft. per day when the building has to be heated. In January the connections were changed to meter the total production, which is running between 90,000 cu. ft. and 95,000 cu. ft. per day. This amounts to almost exactly 1 cu. ft. per capita per day for the sewered population.

The three covered digesters have baffle walls running the length of the tanks, which force the sludge to move the entire length of each tank twice. The open tanks do not have baffles, but the openings connecting successive tanks are located at opposite ends; so the sludge has to travel at least the length of each tank. The openings between the tanks are at the bottom and are approximately 6 by 6 ft. There is no means for separating one tank from the others. In effect, therefore, we have what might be considered one long, well baffled digester which is partly covered. Sludge capacity in the covered portion is better than 1 ft. per capita, with about 3 ft. per capita for the entire system.

On two occasions we have had a condition in the digesters which was unusual in appearance, to say the least. When the plant was first put into operation, the digestion tanks were filled with sewage to hold the first sludge which entered inside the covered tanks. Otherwise the entire series of tanks would have filled simultaneously with undigested sludge. By the method used the water was drawn off from the last tank as it was displaced by the sludge.

A few weeks after digestion had started, an attack of foaming began. The sludge in the covered digesters developed a specific gravity of between 0.6 and 0.7. The pH dropped for awhile as low as 6.0. We added some lime which raised the pH somewhat and attempted to break up the foam by continuously running water sprays, which are built in the top of each gas dome.

As this foaming sludge entered the first open tank it, being lighter, rose to a higher level than the sludge in the next open tank. The entrapped gas in this sludge was gradually released as it passed through the open tanks and the specific gravity increased. There resulted, therefore, a condition in which the sludge in the first open tank was higher than the sludge in the second tank, which was in turn higher than that in the third, and so on. The result was similar in appearance to a staircase with steps 12 inches to 18 inches high. This condition gradually disappeared and in May the sludge stratified and supernatant water appeared.

While this was happening the sludge rose and almost completely filled the gas domes and on two or three occasions the gas lines. The domes were about 3 ft. high. After the foaming disappeared the sludge dropped a foot or two in the domes, but due to the vigorous agitation caused by gas bubbles rising in the domes, sludge was constantly being splashed into the gas lines, and as the gas capacity of the domes was reduced, the release of gas bubbles caused surges in pressure which sometimes blew out the oil seals on the domes.

This condition did not change, so in November the domes and gas lines were raised four feet. This lifted the gas lines sufficiently high to keep sludge from splashing in, and in addition, the increased gas capacity reduced surges in pressure; so the oil seals hold better.

At the time that the domes were being raised it was necessary to lower the sludge level several feet to do the required work.

Immediately after the work was completed the foaming began again and the staircase effect was repeated. The pH of the sludge did not drop this time, remaining at about 7.3. The specific gravity dropped to about 0.7. The condition has not entirely disappeared, although it is better. Supernatant water has not appeared.

Two factors are seen as the possible cause this second time. A large quantity of air was admitted which might have disturbed the anaerobic organism in the covered digesters, and the temperature was lowered appreciably. The latter is, I think, more probably responsible for it. Some considerable time was required to raise the temperature to 84° F. but after it was reached the condition improved rapidly.

## Chemical Treatment

The coagulant used at the plant is ferric chloride. This is made by passing chlorine solution through iron borings and turnings, which we purchase from the railroad shops. Chlorine is bought in ton capacity containers which come fifteen to a carload.

The chlorine is put in solution with two Wallace and Tiernan chlorinators, each having a capacity of 300 lb. per day. The ferric chloride generator consists of three cylindrical tanks 12 ft. deep and 36 inches in diameter. They are made of vitrified tile pipe. Two of these are filled with the iron shavings. Chlorine enters these tanks at the bottom and passes upward through the iron. Ferrous chloride, ferric chloride, or a mixture of the two is formed, depending on the rate of flow, the chlorine concentration, the contact period, and other factors.

We usually try to make ferrous chloride in these two tanks. The solution passes from the top of these tanks to the third tank, entering at the bottom. Additional chlorine is added in this tank to convert the ferrous chloride to ferric chloride. The ferric chloride solution then passes from the top of this tank into the sewage, where it is precipitated as ferric hydroxide.

For some time we kept iron in all three tanks in an attempt to get a larger amount of iron in solution, but better results have been obtained the other way.

When chlorine is put in solution and brought in contact with iron, a number of things can happen. One thing is the production of hydrogen gas. This hydrogen can cause considerable trouble. For example, if one tank is filled with iron, and chlorine solution of uniform concentration is passed through it for several days without changing the rate, we get approximately the following results:

| Time Elapsed From Start of Test Hours | Parts Per Million | | |
|---|---|---|---|
| | Ferrous Iron | Ferric Iron | Total Iron |
| ½ | 2650 | 120 | 2770 |
| 1½ | 2300 | 120 | 2420 |
| 2½ | 1400 | 200 | 1600 |
| 3½ | 400 | 750 | 1150 |
| 4½ | 0 | 850 | 850 |
| 5½ | 0 | 700 | 700 |
| 8 | 0 | 650 | 650 |
| 24 | 0 | 550 | 550 |

As can be seen, the iron concentration first came up to practically the theoretical amount possible, approximately 2800 p.p.m., for a chlorine solution of the strength used, which is about one pound of chlorine to 40 gallons of water. Then it suddenly began to drop and decreased until it reached a figure as low as 550 p.p.m. At the same time the production of ferrous chloride naturally stopped due to the excess of chlorine.

The flow of chlorine solution was then cut off, and as soon as this was done a tremendous amount of gas boiled out from the tank for about ten minutes. After the turbulence had subsided the chlorine supply was started again and the iron content of the solution quickly rose to 2000 p.p.m., only to drop after 2 hours to 1000 p.p.m. The chlorine was shut off, and the evolution of gas again took place.

As we see it, the hydrogen gas gradually coats the iron shavings and prevents the chlorine from coming in contact with the iron. Most of the chlorine channels up through the iron without reacting. Possibly the force of the chlorine solution current, slight though it is, holds the hydrogen against the iron. When this current is suddenly stopped, the pressure is released and the hydrogen liberated. The increase in iron content which follows after the release of the gas seems to substantiate this theory.

Similar release of the gas is accomplished by stirring the iron with a long heavy bar. It is difficult, however, to penetrate much more than the top foot of iron this way. We are thinking of running an air line through the iron and blowing air through it at intervals in an attempt to flush out the entrapped gas.

At present we are alternating the flow through the two iron tanks, changing tanks every two hours, and stirring the iron with a bar about every hour. This is giving fairly good results, and we are able to keep the feed solution fairly uniform in composition, which is, of course, necessary for efficient treatment.

When ferrous chloride comes in contact with hydrogen sulphide, ferrous sulphide is produced. This is black. Therefore, if we note that the sewage is turning black we know that insufficient chlorine is being added to convert all of the ferrous chloride to the ferric state. Likewise the odor of chlorine gas informs us that an excessive amount of chlorine is being added, or as is frequently the case, that the iron needs stirring. Of course we make several analyses daily of the ferric and ferrous iron content, but the color and odor tests warn the operators that something is wrong.

The system we are following at present is giving us about 2000 p.p.m. of ferrous iron in the iron tanks, which is oxidized in the other tank to a solution of about 1400 p.p.m. ferric chloride. Running the chlorinators at their maximum capacity we are able to add approximately 100 pounds of ferric chloride per million gallons for a flow of 6 m.g.d., or 4 p.p.m. Fe.

## Comparison With Other Chemical Plants

This is considerably less than the amounts used at most other places employing chemical precipitation, according to the literature. For example, we find that at Dearborn, Michigan, from April, 1935, to February, 1936, 250 pounds of lime and 305 pounds of ferric chloride were added per m.g. At Perth Amboy, N. J., in July and August, 1935, 650 pounds of lime and 250 pounds ferric chloride per m.g. were used.

In tests at Coney Island 1015 pounds lime and 361 pounds ferric chloride were used per m.g. At the Shades Valley plant in Birmingham during the summer of 1935, an average of 480 pounds of copperas treated with 70 pounds chlorine was used per m.g. This is equivalent on an iron basis to about 300 pounds of ferric chloride. (Source, Calvert, *Sewage Wks. Journal*, May, 1936.)

At York, Nebraska, a smaller plant, 188 pounds ferric chloride and 164 pounds lime were added per m.g. (Source, F. M. Veatch, *Sewage Wks. Journal*, January, 1936.)

The average amount of iron per m.g. that we have used since the plant was started is 18 pounds per m.g. Assuming this to be all converted to ferric chloride, the average would be 53 pounds ferric chloride per m.g. It was not actually all converted to ferric chloride as we did some experimenting with ferrous iron treatment during the year. This also includes times when no treatment was used. However, since ferric iron is more effective than ferrous iron as a coagulant, we shall assume for our purposes in this case that ferric chloride would be at least as effective as the mixtures actually used.

Thus it is seen that our treatment has been much lighter than in other plants, not through choice, but because of limited capacity of equipment.

The following table shows results obtained at various plants:

| Plant | Flow M.G.D. | * Chemical Treatment | | Additional Treatment | Susp. Solids | | | B.O.D. | | | Cost of $FeCl_3$ per M.G. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $FeCl_3$ | Lime | | Raw | Eff. | % Removal | Raw | Eff. | % Removal | |
| Dearborn.. | 2.61 | 305 | 250 | Magnetite Filter | 293 | 24 | 92 | 174 | 42 | 76 | $13.12 |
| Perth Amboy.. | 2.5 (est.) | 250 | 650 | Magnetite Filter | 240 | 29 | 88 | 257 | 100 | 61 | 10.75 |
| Coney Island... | | 361 | 1015 | | 125 | 9 | 93 | 150 | 33 | 78 | 15.52 |
| Birmingham..... | 0.6 | 300† | | Pre. Sed. & sludge return | 124 | 10 | 92 | 85.5 | 12 | 86 | 12.90 |
| York..... | 0.24 | 188 | 164 | | 287 | 55 | 81.7 | 182 | 60 | 66.7 | 8.08 |
| El Paso.... | 6.0 | 53 | | | 328 | 55 | 83.2 | 267 | 112 | 58.1 | 2.28 |
| El Paso Present Treatment.... | 5.5 | 82 | | | | | 87 | | | 74 | 3.53 |

* Lb. per m.g. † Equivalent.

The cost per m.g. for ferric chloride was figured for all of these on the basis of the approximate prices which we pay for chemicals, namely 4c per pound for chlorine and 0.3c per pound for iron. This was done merely for comparison purposes. Actual costs elsewhere, in most cases, are probably lower due to geographical locations.

These figures are given in an attempt to show what might be considered representative results obtained by chemical treatment. It is not intended to show in any way that any one of the plants mentioned is better or worse than the others. Sewages of different cities do not necessarily react similarly to identical treatment. The only comment we will make is that after a certain point is reached, further purification seems to be reached only with excessive cost. It is probable that in the revival of this method of treating sewage, large quantities of chemicals were first added in the hope of getting remarkable results. From what literature we have seen we imagine the trend may be towards somewhat smaller dosages of chemicals in many instances. Additional experiences throughout the country in the next few years will undoubtedly show which way to go.

With the treatment that we are using at present, that is, about 82 pounds of ferric chloride per m.g., we are getting a reduction of approximately 87 per cent of the suspended solids and 74 per cent of the B.O.D.

Ferrous chloride is not very effective as a coagulant, but gives excellent results in controlling odors at the plant.

## Conclusions

On the whole, we feel that the plant is doing at least as much as was expected from it at the time that it was built. Suspended solids removal has been over 80 per cent at all times that chemical treatment has been employed. B.O.D. reduction was only about 55 per cent at first, but this has been steadily improved each month and is now, as stated before, around 75 per cent. It is doubtful that this can be improved much more without other treatment, as the portion of B.O.D. due to matter in solution will probably not yield to this method of treatment.

Mention has been made of difficulties encountered in the making of ferric chloride, as it is an interesting problem. These difficulties will be overcome rapidly as experience is accumulated. Changes in design will continually take place, and in the not too distant future it will probably be done by a simple, fool-proof method.

This and other problems connected with chemical treatment are no more serious than those which in all likelihood occurred when other methods of treatment were going through formative years of development.

Chemical treatment has a definite place in the sewage treatment field, particularly where seasonal treatment is a factor. With the flexibility of which it is capable, it is particularly fitted where there are sudden increases in load on the plant or decreases in volume of dilution water. Where complete treatment is necessary most of the time, other methods, at least at the present time, seem to offer more.

# ACTIVATED CARBON—ITS PLACE IN SEWAGE TREATMENT *

By R. W. Haywood, Jr.

*Technical Service Dept., Industrial Chemical Sales Division, West Va. Pulp and Paper Co., New York City*

One of the most rapidly developing fields in the program for the protection of public health is that of sewage treatment. The increasing complexity of our everyday life is reflected in the waste materials that must be taken care of and the problem of their satisfactory disposal presents a picture that is constantly changing, always from the simple to the complex. Fortunately, there has been a parallel development in treatment methods—improved plant design, more accurate and reliable control of operations, the selection of better trained operators, and the development of new treatment processes, all contributing to greatly improved conditions. Of the new ideas and methods of treatment that are continually appearing, to win or lose favor as investigation proves their merit or lack of merit, one of the more recent developments is the use of activated carbon. Since its introduction into the field of sewage treatment in 1931, it has been adopted as routine treatment by a number of plant operators and it is believed that some of their experiences in using this material are of sufficient value and interest to warrant placing them before this association. It is for this purpose, therefore, that this paper has been written.

## Activated Carbon—What It Is

Activated carbon is well known to water plant operators who have used it for the past eight years. It is a black, finely ground powder, from 90 to 95 per cent pure carbon, that is made from raw materials such as wood charcoal, lignite, or the soluble organic constituents of wood that is being treated for manufacture into paper. These raw materials are subjected to activation by heat treatments that greatly increase their activity, or ability to do the work required of them. A good activated carbon is from twenty to fifty times more efficient than ordinary bone charcoal. One commercial activated carbon on the market today is ground to such an extent that one gram contains 120,000,000,000 particles and it has been estimated that one cubic inch of this material will have a combined internal and external surface of over 20,000 square yards.

## What It Does

Activated carbon has been used successfully to control odors emanating from various sources about the plant, to control pH of the sludge, to improve digestion with accompanying improvement in sludge drying,

* Presented before the Eleventh Annual Conference of the Pennsylvania Sewage Works Association, State College, June 21, 1937.

to reduce and control scum formation, and to assist in controlling bulking of sludge in an activated sludge plant. Other claims have also been made, such as increased gas production, improvement in quality of gas, improved settling in primary settling tanks, etc., but, to date, these claims have been but poorly substantiated, if at all, and are yet to be proved.

## Odor Control

Improper plant operation, whether due to over-loading or to industrial wastes, quickly makes itself known when objectionable odors arise. These may come from open gas vents, as in the case of some Imhoff plants, from poorly digested sludge that must be drawn from the digestion unit to make way for fresh solids, and from sludge that forms when solids settle out in the secondary settling tank. All are equally offensive and demand prompt attention.

Odors from gas vents of Imhoff plants have been satisfactorily taken care of at the plant of the Village of Albion, N. Y., where Mr. Frank Nayman is Chief Operator, and at the plant of the Village of Wanakah, N. Y., which is operated under the direction of Mr. E. B. Stearns, consulting engineer. At Albion activated carbon was mixed in a slurry and poured in the gas vents where it was mixed with the scum by hosing. Not only was the odor from this source eliminated but the scum settled out, leaving the gas vents almost entirely free from any floating solids.

The Wanakah plant is of interest because it is located in a residential section on the shore of Lake Erie, the nearest house being not more than seventy-five yards away. Here the problem of odors from the gas vents of the Imhoff tanks was solved by adding a mixture of activated carbon and lime, made by combining equal parts of these two materials, in a dry state to the gas vents. This was done once each day, about three o'clock in the afternoon. No complaints were received by the authorities after this treatment had been adopted.

Disposal of sludge from the secondary settling tank at Fairport, N. Y., was accomplished with difficulty. Here it was necessary to clean the tank once every two weeks, the accumulated sludge being pumped onto open sludge drying beds where it became the source of abundant and objectionable odors. Mr. Arthur Cary used activated carbon, applying it to the trickling filter effluent, and reported that he was able to wait for five weeks before cleaning the final tank and that the sludge, when placed on the sand beds, dried readily and without unnecessary odors. Mr. Cary is the Superintendent of Public Works of the Village of Fairport and has used activated carbon in the sewage treatment plant there the last two years, starting his treatment in the late winter and continuing it until the middle of May.

Odors from poorly digested sludge were problems faced at both Liberty, N. Y., and the Tryon Park Plant of the City of Rochester, N. Y. Experiences with activated carbon at Liberty have been reported [1] by Mr. John Lawrence, Supt. of Public Works, and Mr. Harry

Eichenouer, Plant Operator. Briefly, when added to the sludge that was being pumped from the settling tanks to the digestors, digestion was stimulated to the extent that, when drawn on the drying beds, it had comparatively no odor and dried quite satisfactorily as compared to the period preceding the use of carbon when it was necessary for the men who removed the sludge from the drying beds to change clothes completely and take a shower after finishing, to rid themselves of the odor emanating from the sludge.

At the Tryon Park Plant, activated carbon was used successfully by Mr. George Yatteau, Chief Operator, to correct odor troubles that occurred when sludge was drawn from Imhoff tanks. At this plant the sludge is drawn off in large lagoons, rather than onto drying beds and, since the plant is located in the immediate vicinity of a residential section, odors from the sludge resulted in numerous complaints which accumulated at one time in the form of a petition to the authorities. Here the carbon was mixed in a slurry and poured in the gas vents and hosed down. Since it has been used there have been no complaints about odors from the lagooned sludge.

### pH Control

Carbon has been used at Walden, N. Y., to control the pH of the sludge, where it is applied to the raw sludge as it is pumped to the digestors. Records from the Walden plant indicate that the operator raised the pH of the sludge from 6.6, a point beyond which he had been unable to increase it, even though 50 pounds of hydrated lime were used every day for this purpose, to a maximum of 7.6, between December 17, 1935 and February 17, 1936. To do this, 35 pounds of carbon were applied daily to an average of 160 cubic feet of sludge just as it was pumped to the digestor. This amount was later decreased until, starting May 17th, the average dose was between 3 and 4 pounds per 160 cubic feet of sludge pumped, the pH being held at 7.0 with this amount. It should be mentioned that the digestor was not operating satisfactorily during the period of lime application but gave no trouble after carbon was added.

### Scum Control

Scum control in the gas vents of an Imhoff tank has already been mentioned as taking place at Albion, N. Y. Control of this layer of accumulated solids was also accomplished at Fairport, N. Y., in a separate sludge digestion unit. On March 19, 1936, the temperature of the unheated tank was 50° F., the ash content of the sludge 32.4 per cent, volatile solids content 67.6 per cent, and the grease content 12.2 per cent. The addition of activated carbon was begun and, by March 30th, 140 pounds had been added by preparing a slurry and introducing it into the discharge side of a sludge circulating pump, thus insuring thorough mixing of the carbon with the sludge. Sludge circulation without the addition of carbon had been routine practice for a number

of years prior to this time but without material effect upon the sludge. In one week, the temperature of the digestor rose to 54° F. and the grease content increased to 19.8 per cent. Carbon was added at the rate of 10 pounds per day until April 25th when the temperature had risen to 56° F. and the grease content to 31.2 per cent. The highest grease content was noted on May 8th when the sludge contained 32.45 per cent. In view of the fact that grease forms a major portion of scum, it seems logical to assume that the increase of this constituent in the sludge could only have come from that source since the nature of the sewage did not change materially during the time carbon was used and, after the application of carbon was stopped, the quantity of grease in the sludge decreased to its original value.

Furthermore, repetition of the same treatment during the spring of 1937 produced parallel results as indicated by the following table:

| Date | 1/1/37 | 2/26/37 | 3/12/37 | 3/25/37 | 4/9/37 | 4/23/37 | 5/5/37 |
|---|---|---|---|---|---|---|---|
| Moisture % | 95.9 | 92.5 | 87.6 | 90.0 | 94.0 | 96.9 | 91.3 |
| pH Value | 6.8 | 7.0 | 7.6 | 7.6 | 6.8 | 6.2 | 6.2 |
| Solids: Volatile, Dry Basis | 68.3 | 76.0 | 71.1 | 72.3 | 69.1 | 70.6 | 70.0 |
| Ash | 31.7 | 24.0 | 28.9 | 27.7 | 30.9 | 29.4 | 30.0 |
| Grease % in sludge | | 12.2 | 13.7 | 26.2 | 18.6 | 18.9 | 20.8 |

Activated carbon was first added on February 13th, when the temperature of the digestor was 52° F.; the last was added on May 14th, when the temperature of the digestor was 59° F. On May 25th, the temperature had risen to 61° F. The average temperature of the sludge in the digestor for four years prior to 1936 when activated carbon was first used, was 54° F. on June 1st. Five hundred ninety-five pounds of activated carbon were used in 1937.[2]

### Activated Sludge Bulking

Indications are that activated carbon can be used to control the particularly aggravating problem of sludge bulking in an activated sludge plant. During the month of July, 1936, and half of September, it was used at the plant of the City of High Point, N. C., by Mr. E. H. Moss, Superintendent of Plants, at the rate of approximately 4 p.p.m. It was applied to the mixed liquor in the mixing chamber ahead of aeration tanks and resulted in a noticeable shrinkage in the sludge blanket in the settling basins and a decrease in the volumetric solids with improvement in vacuum filter operation.

### Application and Dose

The point of application of activated carbon in a sewage treatment plant seems to be governed largely by the problem to be solved and the work that it is expected to do. Local factors are of primary importance and only a close study of such conditions will permit the

selection of the most advantageous point to apply this material. Actual doses vary widely from plant to plant, but an average seems to be about 4 p.p.m. However, this should be considered only an indication of the starting point from which the best dose for the particular problem to be solved can be determined. It has been found that results are not instantaneous but are secured only by continued and intelligently controlled application together with the best possible plant operation.

## Summary

1. Activated carbon has been used successfully to control odors from the gas vents of Imhoff tanks, from poorly digested sludge, and from secondary, or humus tank sludge.

2. Activated carbon has been successfully used to control pH of sludge in digestors.

3. Activated carbon has been successfully used in stimulating digestion which resulted in increased speed of sludge drying.

4. Activated carbon has been successfully used to control scum in gas vents of Imhoff tanks and in separate sludge digestion units.

5. Activated carbon has been successfully used to control bulking of activated sludge in secondary settling tanks.

6. Points of application depend on local factors and are controlled largely by the work to be done.

7. The optimum dose must be determined by the operator using activated carbon but a review of the plants using it indicates that an average of 4 p.p.m. is usually used.

### References

1. "Activated Carbon Aids Sludge Digestion at Liberty." John Lawrence and Harry Eichenouer. *Public Works*, January, 1936.
2. Personal letter from Arthur Cary to writer.

## Discussion

By Eugene B. Swineheart

*Superintendent, Sewage Treatment Plant, Pottstown, Pa.*

I have the following comments to make upon Mr. Haywood's paper based on my experiences with activated carbon, which has been used in our plant since October, 1936.

All references to carbon dosage mentioned, refer to carbon fed to the influent of our No. 1 and No. 2 settling tanks. Sewage passing through tanks No. 3 and No. 4 did not receive any treatment but the raw sludge from these tanks was treated with 12 lb. of hydrated lime per day just as it was pumped to No. 2 digestor.

### Effect on Temperature of Sludge in Digestor

At the Pottstown plant No. 1 digestor was always approximately 2° F lower than No. 2 although the temperature and volume of the

heating water to the two tanks was the same. Since the addition of activated carbon to No. 1 digestor, there has constantly been a temperature equal to, and most of the time 2° above, No. 2 digestor.

### pH Control of Sludge

Several months after the Pottstown plant was put into operation the supernatant liquor from the digestion tanks had a pH of 6.9 and the digested sludges, 7.5 or 7.6. This condition held until the discontinuance of lime to No. 1 digestor and the treating of the influent to No. 1 and No. 2 settling tanks. It might be wise to say here that sludge from these tanks has been pumped only to No. 1 digestor since activated carbon has been used while the sludge from tanks No. 3 and No. 4 has been pumped only to No. 2 digestor. Shortly after this, the pH of the supernatant liquor from this digestor dropped to 6.7 and the pH of the ripe sludge dropped to 7.4 at which point it remains at the present time.

### Effect on Gas Production

Because of the manner in which the influent enters the distribution channel to the settling tanks, for several months the actual distribution of solids was not nearly equal that is, No. 3 and No. 4 tanks received the bulk of the solids as indicated by the amount of sludge drawn and and solids determinations made on the tank influents. Finally, by the adjustment of the division gate we were able to get practically an equal amount of settled sludge from all four tanks. Since that time No. 1 digestor (with activated carbon to the influent) has consistently produced more gas than No. 2 digestor (with limed sludge). The following table shows average daily gas flows since the plant was started:

| Year | Average Daily Gas Flow |
|---|---|
| 1933—No. 1 digestor started in July | 6.4 thousand cu. ft. |
| No. 2 digestor started in October | |
| 1934 | 7.4 |
| 1935 | 7.4 |
| 1936 | 8.2 |
| 1937—to June 15th | 9.0 |

### More Rapid Drying and Drainability of Sludge

This is a subject upon which it is hard to give a reasonable answer, because of conditions at the plant. The sludge flows by gravity to the drying beds through a 12 in. line which is depressed approximately 8 in. for a distance of 90 ft. To run the sludge to the beds it has been necessary to use two to three parts of tap water per part of sludge. There is a record of one bed which showed fairly rapid drying. This received sludge from No. 1 digestor, approximately 8 in. deep, which dried to 2 in. and could be forked off at the end of nine days. The sludge had cracked on the bed, the cracks being from 1 in. to 2 in. wide. However, we do not feel that there has been any marked difference in the drying time of the carbon-treated and the untreated sludge. This may be due to existing local conditions.

### Decrease in Odor of Sludge

In our opinion there is no noticeable difference in the ripe sludge as run to the beds. This is probably due to the fact that all sludges were well digested, with a pH of 7.5 to 7.6 and were very black, with a tarry odor.

There is a pronounced difference in the odor of the raw sludge drawn from the two batteries of settling tanks. The carbon-treated sludge gives off on inoffensive, medicated odor which is in marked contrast to the fecal and sulphide odors from the sludge that has not been treated with carbon.

### Scum on Settling Tanks

The two settling tanks, Nos. 1 and 2, treated with activated carbon, show decidedly less floating solids than tanks Nos. 3 and 4 which have not been treated with carbon. This has been far more noticeable since the warmer weather. Practically no large floating masses rise to the surface when sludge collectors are operated in the carbon-treated tanks, whereas, in the other tanks, floating sludge is much more noticeable.

### Application and Dose

We have tried varying doses of carbon since this treatment was first begun and are feeding at present at the rate of 54 lb. per m.g. We believe that it is a question of how much carbon the sewage will absorb rather than how much will settle out in the settling tanks. These thoughts are based upon the following experiences: We found that feeding carbon at a rate of 4 p.p.m. over the whole twenty-four hours caused the tanks to appear very black in the morning, although the retention period during the night increased to between 18 and 20 hours. However, feeding at the same rate during the day, with the detention period reduced to from 4 to 5 hours, the carbon was not noticeable. In other words, the tanks did not appear so dark. Thus it seems evident that the carbon is taken up by the sewage solids. During the last two and one half months our procedure has been changed so that we now feed 6 pounds between the hours of 8 P.M. and 8 A.M. and 29 pounds between the hours of 8 A.M. and 8 P.M. The average flow through these two tanks during the twenty-four hours, is 650,000 gallons. The above amounts of activated carbon are readily absorbed by the sewage and the tanks are not noticeably over-dosed at any time.

Mr. J. W. Hood (Ridgewood, N. J.): Briefly, the reconstruction of the Ridgewood plant included the construction of a rigid roof sludge digestor, 50 ft. in diameter, which was put into operation on April 1, 1937. About all I have to report is a log of the digestor operation.

Approximately 100,000 gallons of old sludge were transferred from an existing digestor, and approximately 167,000 gallons of raw sewage were added to fill the tank to capacity. The tank is mechanically equipped and is provided with adequate heating coils.

On April 15th, gas production was noted, but it was too dilute to burn. The pH content was 6.4, and lime was added in solution through the medium of a sludge pump to correct this condition. Slight foaming was experienced at this time, which subsided when recirculation was inagurated. Daily liming of the contents finally resulted in the increase of the pH to 6.9 on May 26th. Application of lime at the tank was omitted, but continued at the pump suction.

On May 28th, serious foaming commenced during the night and penetrated the gas line and meter. Sludge was drawn from the bottom of the digestor and onto the sludge drying beds. Recirculation helped to hold down the foaming temporarily. Six hundred pounds of activated carbon was ordered, and on May 29th an initial dose of 350 pounds of activated carbon was applied through the gas dome. The surface tension of the sludge was relievd and the foaming subsided.

On May 30th, two hundred pounds of activated carbon was added through the gas dome, again with marked effect. The digestor was temporarily out of service.

On May 31st, there was an application of activated carbon by means of a dry feeder to the sludge pump suction.

June 1st, the digestor remained quiet. Supernatant was in the middle of tank and was of poor quality.

On June 2d, we appealed to the Industrial Chemical Sales for assistance, and they arranged to send a further supply of activated carbon.

On June 3d, the digestor was again put in operation, and at 3 P.M. on June 4th there was an indication of a fresh outbreak of foaming. An analysis of sludge gas disclosed 63 per cent $CH_4$ and 35 per cent $CO_2$. We decided to add additional lime to precipitate $CaCO_3$ and to reduce the carbon dioxide content of the gas. Five hundred pounds of lime in solution was added, applied at the gas dome, and recirculation continued all night. No outbreak of foaming occurred during the night.

On June 5th, at 8:30 A.M., serious foaming broke loose through the dome and supernatant overflowed. The sludge drying beds were again resorted to in order to prevent overflowing of foam at the gas dome. Timely arrival of carbon enabled commencement of application. Throughout the day 1,800 pounds were applied in the slurry, without the former immediate effects. More sludge was drawn every hour until 4 P.M. when slight abatement was noticeable. Gas line was flushed and dome replaced. Unit was taken out of service.

On June 6th, all was quiet during the night. Settling was noted in the overflows. Gas production good and waste gas burner remained lit. pH of foam 7.4 of sludge 7.0.

On June 7th, contents subsiding. No fresh sludge being introduced. Temperature of contents 75° F.

On June 8th, fresh sludge introduced from final clarifier and gas production good. No foaming.

On June 9th, added 350 pounds of activated carbon. Condition slightly improved. Gas production decreased.

On June 10th, no foaming. Temperature of contents 75° F.

On June 11th unit restored to full service and fresh sludge pumped from clarifiers Nos. 1 and 2. Thirty-five pounds of Nuchar added through a small pipe in the roof of the digestor, directly to the top of the scum.

On June 12th the unit was in full service, no foaming, gas production improving, waste gas burner lit throughout the day.

On June 13th, the sludge contents 74°. Second top overflow, liquid again, supernatant pH 7.1. Sludge showed tendency to foam at 1 A.M. Settled down 12 inches below overflow at 8 A.M. Thirty-five pounds of Nuchar added.

On June 14th, contents subsided during the night 14 inches. Unit in full service.

On June 15th, 35 pounds of Nuchar added. Contents settled 15 inches more. Supernatant clearing. No overflow for two days. Foam apparently subsiding. Gas production good.

On June 16th, 35 pounds of Nuchar added. Contents settled 12 inches more. No overflow. Gas production good.

On June 17th, 35 pounds of Nuchar added. Contents settled 6 inches more. No overflow. Gas production decreasing. Temperature 72.°

On June 18th, the same record as day previous.

On June 19th restored digestor to full operation, adding sludge from all clarifiers. Supernatant liquor turbid. Digestor in full operation. Gas production low. Temperature 71°, pH 7.0.

## Summary

Summarizing the experience, it would appear that too rapid digestion resulted in gasification and entrainment of the gas in the sludge which apparently had considerable tension in its particles. This resulted in the rapid formation of foam and gave rise to the operative difficulties. The discontinuance of heating, from the commencement of the foaming, combined with the application of the activated carbon in slurry, directly onto the foam, resulted in the restoration of the unit to full service in about ten days time. However, the supernatant still remains turbid and creates a problem at the point of return to the sewage flow at the plant influent.

President Cleland: Is there any further discussion?

Mr. J. R. Harvey (Pa. Dept. of Health, Meadville, Pa.): I would like to ask Mr. Haywood a question. Do you attribute the increase in temperature in the digestion tank to activated carbon, and if so, how is it brought about?

Mr. Haywood: I would hesitate to say, although it may be due to activity of the sludge.

Mr. H. Heukelekian (N. J. Agri. Exper. Station): I don't see how it will increase the temperature. When the activity of digestive solids is increased by the addition of ripe sludge, there would be no difference in the temperature under identical conditions.

MR. S. I. ZACK (Filtration Equipment Corp.): Was the carbon added to the sewage?

MR. HAYWOOD: Yes.

MR. ZACK: Was there any coagulation or settling due to the adding of the carbon?

MR. HAYWOD: Not to my knowledge.

MR. ZACK: How much was added?

MR. HAYWOOD: An average dosage of 4 p.p.m.

MR. ZACK: And the addition of carbon was for the purpose of aiding digestion?

MR. HAYWOOD: For several reasons. The point of applicaton varies according to what you want to do.

MR. ZACK: What is the commercial value of carbon?

MR. HAYWOOD: It varies according to the quantity you buy. The average is 6½ cents a pound.

MR. ZACK: That is f.o.b. the plant?

MR. HAYWOOD: F.o.b. the works.

DR. WILLEM RUDOLFS (N. J. Agri. Exper. Station): Answering Mr. Zack's question, laboratory experiments have shown that activated carbon does not affect the coagulation.

# STARTING AND OPERATING THE COATESVILLE, PENNSYLVANIA, SEWAGE TREATMENT WORKS *

By William C. Emigh

*City Engineer, Coatesville, Pa.*

Coatesville has a population of about 15,000. It is on the watershed of the west branch of Brandywine Creek which, at the point at which the stream leaves the city, has an area of approximately fifty-two square miles. The sewage of the city is principally of domestic origin and that from industrial plants is almost entirely of the sanitary type. Trade wastes, therefore, do not constitute a problem in the treatment of the sewage at the present time. In addition to the sewage originating within the city, that from a hospital of the United States Veterans' Administration, located northeast of the city boundary, together with that of an aggregate population of perhaps six hundred persons residing beyond the boundaries, flows into the city sewers. Although the city has separate systems of storm and sanitary sewers there is still some water from roofs entering the sanitary system which causes a rapid increase in flow during periods of intense rainfall. Some ground water also reaches the sewers.

The sewage treatment works are located on the east bank of Brandywine Creek just south of the city boundary on land formerly a part of a steel plant of the Bethlehem Steel Company (Fig. 1). The construction of the sewage treatment works was completed in the spring of 1933. The plant was not operated, however, until the spring of 1936. The treatment works, briefly, consist of: pumps which raise the sewage to a sufficient elevation to permit it to flow through the plant and to the point of outfall by gravity; a mechanically-cleaned bar screen; a detritor providing for both grit and grease removal; four primary settling tanks provided with flight conveyors for moving the deposited sludge to hoppers at the ends of the tanks; aeration tanks (Fig. 2) for the activated sludge process; final settling tanks, also provided with conveyor equipment; a tank to provide a period of chlorine contact; and an outfall sewer. The outfall sewer extends to a point upstream from the plant in order to make the effluent available to a local steel plant, thus augmenting the normal stream flow used for cooling purposes. The treatment works also include four sludge digestion tanks with concrete roofs; sludge drying beds with glass covers; a sludge control house containing sludge pumps, gas fired sludge heating boilers and accessory equipment; and a gas holder of 10,000 cubic feet capacity.

In placing the plant in operation it was deemed feasible and advisable for several reasons to operate, for a time, only the units providing primary treatment. The secondary treatment, or activated

* Presented before the Eleventh Annual Conference of the Pennsylvania Sewage Works Association, State College, June 21, 1937.

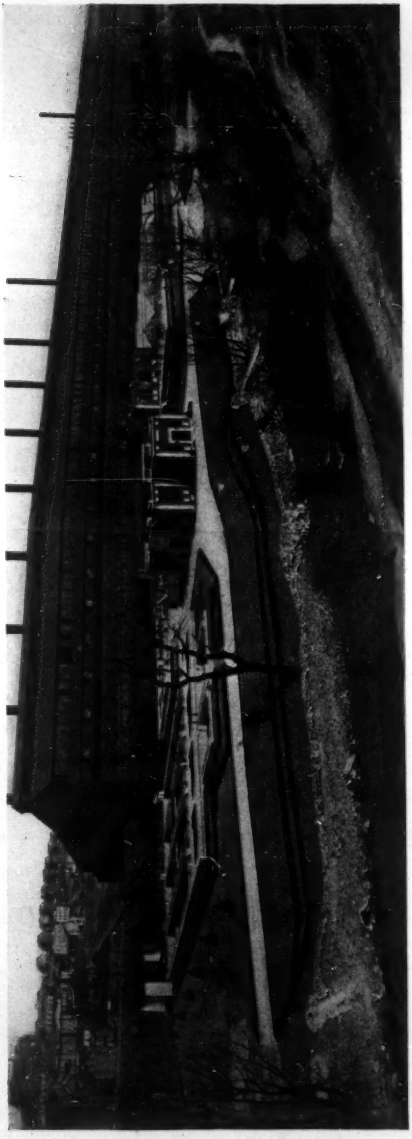


FIG. 1.—General view of Coatesville sewage treatment works.

sludge process, has not yet been placed in operation. It is proposed, therefore, to discuss only the operation of the primary treatment units.

Sewage is conducted to the plant by a 30-inch interceptor along the east bank of Brandywine Creek. It enters the pumping station through a hydraulically operated sluice gate and passes through an inclined bar rack with 2½-inch clear openings, in a tangential direction, into two circular, hopper bottom sumps. The sump room is separated from the pump room by a heavy concrete wall through which a suction pipe passes from each sump.

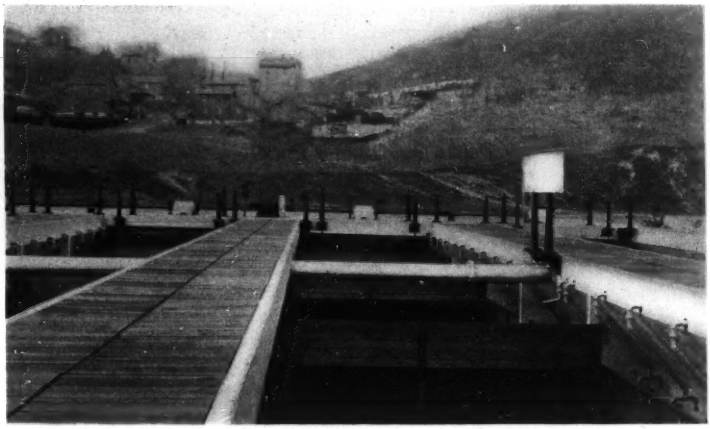


FIG. 2.—Aeration tank looking in direction of flow.

The raw sewage pumping equipment consists of three vertical centrifugal pumps manufactured by the Buffalo Pump Company, each having a capacity of 2,100 gallons per minute. The pumps are of variable speed type and provide for variation of delivery from 500 gallons per minute, through 200 gallons per minute increments, to 2,100 gallons per minute. The operation is automatically controlled by a float rising and falling with the fluctuation in level in the suction sumps. The sequence of operation begins in the first stage at 500 gallons per minute discharge and increases through the several stages to the capacity of a single pump. In passing into the next stage the first pump is slowed down to a delivery of 1,100 gallons per minute and a second pump comes in at the same rate. With increased flow and consequent rise in the level in the sumps, the delivery of the two pumps increases by 400 gallons per minute increments to the capacity of the two units, or 4,200 gallons per minute. Not more than two pumps operate at one time.

These pumps have operated quite satisfactorily but it has been necessary at not infrequent intervals to take a pump out of service for cleaning. In an effort to increase the lengths of run of the pumps,

additional bars were put in the rack ahead of the pumps thus decreasing the clear space to one inch. These additional bars extend only a few inches above the normal flow level so that, should they become clogged, the sewage is free to pass through the larger original openings.

As originally constructed, the float wells were connected to the pump suction line. The hydraulics of the flow in the suction line interfered with the maintenance of equal levels in the sumps and the float wells. The float wells, therefore, have been connected directly to the sumps by running a pipe through the wall between the pump room and the sumps.

The venturi meter tube measuring the flow of raw sewage is on the vertical section of the force main from the pumps. This meter has operated satisfactorily, giving very little trouble. The stage operation of the pumps for the most part produces a stepped graph which does not represent at any particular moment the exact flow of sewage entering the sumps.

The mechanically cleaned bar screen through which the sewage flows after being raised by the pumps, is of a well known type with timed relay operation, and requires no detailed description. The quantity of the screenings per million gallons of sewage has varied over a wide range. Sometimes it is possible to account for this by a recent rain and at other times it has been difficult to understand the variation. During dry weather flow the screenings generally run from one to one and one-half cubic feet per million gallons of sewage.

The flow of sewage to the plant averaged during the first year of operation approximately 1,940,000 gallons per day. The minimum average daily flow during any week was 1,631,000 gallons and the maximum 2,441,000 gallons. In time of heavy rainfall the flow has reached a rate of nearly 6,000,000 gallons per day. The temperature of the sewage has varied from a minimum of 49° F. to a maximum of 73° F. Its pH has ranged from 7.2 to 7.4 with occasional readings slightly above or below these figures. The pH of the raw sludge has usually been 6.2 or 6.3.

Inasmuch as the use of only the primary treatment units did not include the operation of the compressors, the detritor has not been operated as intended and its efficiency can not yet be fairly determined. The design of this grit chamber and grease separator was based upon the spiral velocity of the sewage induced by the introduction of air through porous diffusers on one side of each unit. Without the use of air it was deemed advisable to attempt to short-circuit the flow by means of additional baffles. Although not functioning in the way the designer intended, it has caused no trouble nor has any large quantity of organic matter settled in the tanks. The grit and other material removed in this detritor has varied from none, to five or six cubic feet per day.

From the detritor the sewage flows to the distributing channels of four primary settling tanks (Fig. 3). It passes from these channels into the tanks through a series of ports and is diffused upon entering the tanks by slat baffles (Fig. 4). A venturi tube is installed on the pipe leading to each primary settling tank. The pressure differential

in the throat and main belt is indicated by the relative heights of floats. It is thus possible to judge of the relative volume of sewage entering the several tanks and to rectify inequalities of distribution. As has been

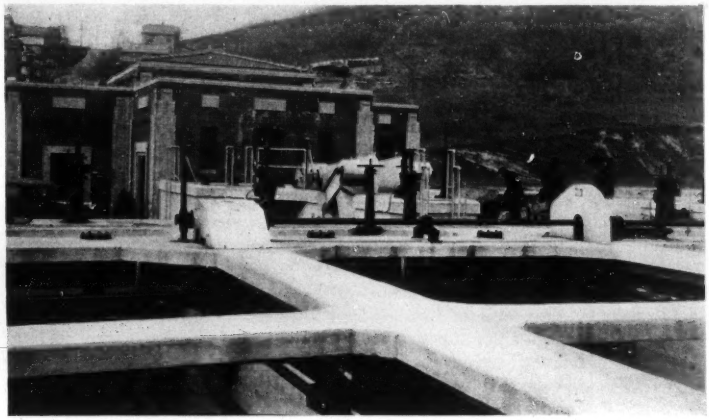


FIG. 3.—Primary settling tanks, detritor and pumping station.

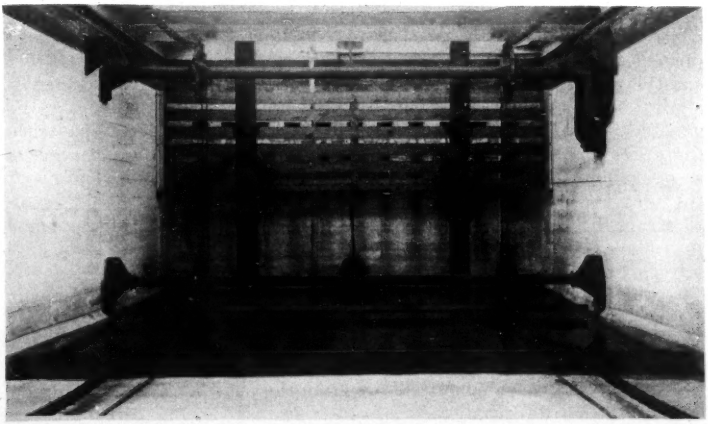


FIG. 4.—Influent end, interior of primary settling tank.

stated, the settling tanks are provided with flight conveyors to move the sludge from the flat floor to the two inverted pyramidal hoppers in each tank. This equipment is of the well-known Link-Belt Company manufacture and needs no description in detail. The return tracks of the

flights are at the surface level, thus moving the scum to the outlet ends of the tanks where revolvable slotted pipes are provided for its removal.

The flight conveyors are being operated four or five times a day for periods of about one-half hour each. During the warmer season of the year some raw sludge has risen from the hoppers. It has not always been possible to settle this sludge by hosing or other methods tried but the quantity has not been sufficient to create any particularly objectionable conditions. Scum has usually been removed about once a day although during cold winter weather that has not always been necessary.

The usual method of removing sludge from the hoppers at the inlet ends of the primary settling tanks by hydrostatic pressure, is employed with a head of about four feet. Each of the eight sluice gates which permit sludge to flow from the hoppers into a sludge channel, is electrically operated. From the sludge channel the sludge is piped to a sump beneath the basement floor in the sludge control building. As it flows into this sump it passes through another electrically operated sluice gate. Automatic operation of these gates is provided. When the low level elevation of sludge in the sump is reached either two, four, or all eight of the gates at the primary settling tanks open. When the high level elevation in the sump is reached these gates close. Should they fail to close and the level in the sump continue to rise, the gate at the sump will automatically close. This latter condition, however, permits the sludge to rise through a manhole and overflow the grounds. When the sludge in the sump has been pumped down to the low level, the gates will again open, admitting more sludge. If the automatic control is set for two gates to open at a time the entire eight will be opened in sequence in groups of two, with successive fillings and emptyings of the sumps. In operation it has been found that the possibility of failure of the gates to close, resulting in sludge flooding the grounds, is sufficiently real to render manual control of the switches preferable to automatic operation and, for the most part, they have been so operated. Sludge has usually been removed from the primary settling tanks twice each day.

From the sumps the raw sludge is raised by two diaphragm pumps to a sludge heater. This is a water heated boiler with 76 four-inch tubes about fourteen feet long through which the sludge passes in series. The water supplied to these tanks is heated in gas fired boilers and is circulated by centrifugal pumps.

In operation the intent has been to raise the temperature of the raw sludge to, or a little higher than, the temperature of the sludge in the digestion tanks to which it flows from the heater. It has been difficult to do this uniformly, for several reasons. Owing principally to occasional partial or complete clogging of the ball valves in the diaphragm pumps, the rate of pumpage varies considerably. Furthermore, as sludge and hot water remain in the heater during the intervals between periods of operation, during which time opportunity is afforded for more complete heat transfer than during operation, the first sludge to leave the heater after again starting operation is warmer

than that which passes more quickly through it. At a normal rate of pumpage it may require about fifteen minutes for the sludge to pass through the heater. The sludge enters the heater at the bottom and leaves at the top whereas the flow of heating water is in the opposite direction. During the winter the drop in temperature of the heating water while passing through the heater was about 20° F. The temperature of the sludge was generally raised to from 80° to 85°. During the spring, summer, and early fall no attempt was made to heat the sludge.

From the heater the raw sludge is piped to the sludge digestion tanks of which there are four. When, in the fall, colder weather made heating of the sludge in the digestion tanks desirable, only two of these tanks were kept in service. It is now believed that it will be possible to operate with only one. This condition may be quite different when the secondary units of the plant are placed in operation. The heating equipment consists of hot water coils around the sides of each tank. The same boilers are used for the sludge heater and the digestion tanks. The tanks are provided with hollow tile and concrete decks and provision is made for the collection of gas. Decanting valves are provided which permit drawing off supernatant liquid over a vertical range of about ten feet. The control of elevation at which the liquid is drawn is by means of floor stands on the decks of the tanks.

Eight vertical centrifugal agitating pumps are provided, one for each of the two hoppers in each tank. These pumps make it possible to raise sludge from the bottoms of the hoppers to the surface. The pumps are intermittently operated. During the operation of the agitator the liberation of gas is greatly increased. In fact, relatively little gas is obtained from the tanks at other times. Apparently the agitation of the sludge so depletes it of entrained gas that an opportunity is then afforded for storage of the gas in the sludge as it is produced.

Nearly all of the production of gas in these tanks during digestion has appeared to take place within a few days of the introduction of raw sludge. Illustrating this, sludge had been pumped daily into No. 2 tank for some time prior to and until May 27th of this year on which day the pumpage was diverted to No. 1 tank. From the 23d to the 27th the average production of gas from No. 2 tank had been 8,400 cubic feet per day. On the 28th only 4,100 cubic feet were produced and on the 29th and 30th no gas was obtained from the tank. On the 31st sludge was drawn.

Considerable difficulty has been experienced in collecting gas owing to leakage from the digestion tanks. As stated, the decks of the tanks are of hollow tile and concrete construction. Expansion joints were provided in the decks around the walls of each tank and it has been principally at these joints that leakage has occurred. Considerable effort has been expended in making the joints tight but so far without entire success. For this added reason it is desirable to use as few tanks as are required to accommodate the sludge.

An interesting feature of the gas leakage has been the relation found to exist between the atmospheric temperature and the net gas production. During the winter, graphs were plotted, one showing the average daily mean of maximum and minimum temperatures for weekly periods and the other showing the average daily net production of gas for the same periods. For a considerable time a close relation seemed to exist with an increase of gas production with higher average temperatures. It appears that the lower temperatures contracted the decks of the tanks thus permitting the loss of larger quantities of gas.

During the winter and spring the operating procedure followed was to pump raw sewage into one tank until it was no longer possible to draw out enough supernatant liquid daily to make room for the day's volume of raw sludge. The tank was then allowed to stand for several days, during which time the raw sewage would be diverted to another tank, after which sludge was drawn from the first tank. This principle of operation has been unsatisfactory owing to the fact that, following the change-over of the raw sludge, the gas production was greatly decreased. It appeared that the contents of the tank had been so long inactive that it took some time to start gas production again. This spring, for a short period, alternating daily the tank into which the raw sewage was pumped, was tried. This did not produce satisfactory results and at present an attempt is being made to use one tank only.

The provisions for drying sludge consist of ten under-drained drying beds, each approximately eleven feet by one hundred feet, all glass enclosed. Industrial tracks and side dump cars were not included in the original contract but were installed during the first year of operation. The tracks run to, and along, the top of a retaining wall from which the cars can be dumped directly into trucks on a lower level. Sludge is drawn from the digestion tanks into a channel extending along the ends of the series of drying beds. It is thus possible to draw from any tank to any bed. Supernatant liquid is drawn from the digestion tanks into the same channel. From the channel, sludge or liquid may be run into small tanks in the sludge control house where lime or other chemicals may be added and agitation effected. The contents of the small tanks can be discharged into the raw sludge sumps or into the interceptor before it enters the raw sewage sumps.

When drawing sludge or supernatant liquid, in order to avoid the creation of a vacuum in the digestion tanks which might draw in air, it has been necessary to watch the pressure and rate of drawing carefully. A meter is installed on the gas line from each digestion tank. The original meters did not permit gas to flow in reverse direction. These meters were replaced with meters especially built for this type of service and which permitted and registered flow in either direction. Thus an actual gas production is recorded even though gas is returned to the tanks at times of drawing.

A pressure booster is used on the gas lines to force the gas into the gas holder. It operates automatically as the pressure builds up in the digestion tanks. In order to prevent a back-flow of gas from the

holder when the booster is idle but to permit gas to flow back into a digestion tank from which sludge or liquid is being drawn, two gas regulators of stock design were placed in parallel on the booster discharge line. One permits gas to flow back when the pressure on the tank side approaches zero. The other is placed in reverse position and so arranged as to act as a check valve preventing back-flow through it.

No difficulty whatever has been experienced in producing a satisfactorily digested sludge. During the spring, summer, and early fall all four tanks were used and good sludge was obtained from each. Digested sludge from nearby Imhoff tanks had been used in one digestion tank and activated carbon had been used in another. There was no noticeable difference in the sludge from either of these tanks as compared to the tanks in which neither digested sludge nor carbon had

FIG. 5.—Sludge drying beds looking away from digestion tanks.

been added. Possibly the period of three years during which the tanks contained septic sewage had some effect in starting digestion. From approximately the beginning of operation until early in the year 1937, lime was added almost daily to the contents of the digestion tanks. Since that time no lime has been used. pH readings of the supernatant liquid have been taken daily. During the earlier months of operation there was a tendency for the sludge to develop a lower pH but this was checked by the use of lime. The readings have been, for the most part, about 7.0. The pH of the sludge itself can only be satisfactorily observed at times of drawing sludge to the drying beds. This has decreased from 7.4 in November to 6.7 at the last drawing in May. The physical characteristics of the sludge have not appeared to change. It is quite possible that it will be desirable to resume the addition of lime.

The first sludge was drawn on August 1, 1936 (Fig. 5). In all, there have been twenty-four drawings averaging 1,000 cubic feet of wet

sludge each. The minimum drying period has been fourteen days. Most of the sludge has been left on the bed longer than necessary. Sludge with a moisture content of seventy-five per cent has been removed without difficulty. There has been a demand at all times for more than was produced.

A venturi meter was provided on the raw sludge force main between the pumps and the heater. This has never operated satisfactorily although piping has been changed and back-flow orifices installed. The capacity of the meter is large compared to the sludge flow, which fact, combined with the nature of the material flowing through it, has discouraged further efforts to operate this equipment. The meter is not necessary for the keeping of adequate records inasmuch as an indicating float is provided for each sludge digestion tank. This is not intended to cast any reflection upon the use of venturi meters for sludge measurement. It appears that our meter is considerably larger than it should be for the rate of pumpage, which is probably a large factor in its poor operation. As stated, its use is not necessary in order to keep adequate records as to the amount of sludge pumped into the digestion tank. Before and after the drawing of supernatant liquid, or the pumpage of raw sludge, or the drawing of digested sludge, the position of the indicating floats is carefully noted and the amount of sludge or supernatant liquid pumped or drawn is readily obtained, probably with at least as great accuracy as could be expected with the meter.

A pressure water system using plant effluent is provided for flushing purposes about the plant. It consists of a centrifugal pump and tank with automatic control and includes no special features. The water is piped to all parts of the plant.

Recording equipment is provided for the raw sewage venturi meter, the level in the raw sewage sumps, the pressure on the discharge line of each of the three raw sewage pumps, the pressure on the flushing system, the temperature of the sludge entering and leaving the sludge heater, the temperature of the water in the return line of the circulating hot water coils of the sludge digestion tanks, the raw sludge venturi meter, the venturi meter on the air main and the pressure on the return sludge lines. The last two, having to do only with the secondary treatment, have not yet been used.

The firm of Remington, Vosbury and Goff designed the treatment works and supervised its construction. William Eisenberg and Sons, Inc., were general contractors. All mechanical equipment was under sub-contract to M. L. Bayard and Co., Inc. During the first year of operation several minor changes were made, some of which have already been mentioned. To reduce the hazard of night operation, flood lights were installed which give ample illumination around all tanks and the larger part of the grounds. The plant has also been enclosed with a substantial fence.

### Discussion

President Cleland: Now, are there any questions?

Member: What was the cost of that plant in Coatesville, Mr. Emigh?

MR. EMIGH: The cost was $350,000.00.

MR. F. E. DANIELS (Chief Chemist, Pennsylvania Department of Health, Harrisburg, Pa.): Mr. Emigh's paper is very interesting. Although what I am about to say may at first seem irrelevant I think if you will bear with me, you will find that it has some bearing upon the Coatesville plant, and especially upon activated sludge plants in general.

Thirty years ago it fell to my lot to supervise the actual operation of all sorts of sewage disposal plants, and I kept that up very religiously for quite awhile. Although at that time activated sludge plants had not come into existence, those of you who have read my little book, which was written twenty years ago, will remember that I touched upon a great many points, and that many of those points are still fundamental principles which the operators and many of the designing engineers should know.

I have visited Mr. Emigh's plant, and in that visit there were three particular things that stood out—not particularly as sore thumbs, but they stood out just the same:

*First.* Pumping unscreened sewage.

The pumping of unscreened sewage, in my estimation, is questionable. I don't mean to say that it can't be done, and that it isn't being done satisfactorily in many cases, but wherever it can be avoided we should avoid it. Let us get effective screens in ahead of the pumps. It will save a lot of grief to the operator. I am talking now more particularly from the point of view of the operator than the fellow who is trying to pry out a job from the City Council by reason of cutting the cost of his plant down to the limit.

*Second.* Use of designer's inventions in lieu of well tried standard equipment.

Glory be to the engineer who goes beyond the beaten path and gets something good—well, I have some more remarks to make about that later.

*Third.* Need for skilled operation, with careful laboratory control.

You will notice that I said "need for" and not "lack of," for I am not criticising Mr. Emigh's plant for lack of skill of control. But a plant such as his certainly requires a man who knows his job if it is to be operated satisfactorily.

Human hindsight is often much better than foresight, and you have noted the remarks that Mr. Emigh made regarding putting a float control to measure the head in a tank, on a pipe that is carrying a flowing liquid from the tanks. Someone just overlooked the hydraulics.

And there is the slotted pipe they have for removing scum from the settling tanks. It is a rather simple arrangement for drawing off the scum from their tanks. It is merely a horizontal pipe, with a longitudinal slot, arranged so that by rotating the pipe, by means of an arm, around its axis, the slot is depressed below the surface of the sewage and the scum is floated into the pipe for removal from the tank. There was a little oversight in the design. They didn't realize that a large amount of scum would accumulate back of this pipe. The lever by

which this pipe was rotated was so placed that the slot could not be rotated backward to submerge its rear edge. Mr. Emigh had to bend the lever over and fix the pipe so that it would revolve either way, and thus permit scum to be drawn into the pipe from either side. Another point. There is need for scum baffles within an inch of the overflow weir. You will be surprised how much more fine material you will intercept with such a baffle than with one placed two feet upstream from the weir.

Mr. Emigh mentioned something about the pressure system used for flushing, and of using the plant effluent for washing up around the plant. In my estimation the system of flushing with plant effluent is inferior to city water pressure, and where clean water can be piped into a sewage disposal plant it should be done. Many of the sewage disposal plants in the state have been badly handicapped through lack of clean water for washing up, and it seems to me that it is a makeshift to use the plant effluent for this purpose. I know that in one case a pipe line providing a potable water supply was run into a plant as a W.P.A. project.

A few minutes ago I referred to the need for skilled operation with careful laboratory control. The growing practice of representing that a plant of some particular engineer's design will run itself, should be frowned upon, if not openly condemned. A visit to the Coatesville plant will immediately disclose the complex equipment there installed, and will convince one that the operation of such a plant is no job for a greenhorn.

There is much talk about a year's operation of a plant by the designer. Designers frequently would make the poorest operators. If designers could be made responsible for proper operation of plants, much good might come. But so many times the word "responsible" is only a joke. I will say on the other hand, that if some of our designers could have had an apprenticeship in the actual operation of a plant they would certainly make better designers. They might not make better operators than others, but they would make better designers.

Where are we to get good operators? That is a long story, and if I started on it I would still be talking when you rang the bell.

How can an operator become good?

In these days of rapid changes, and new gadgets, one is often at a loss where to turn for knowledge. Experience is still the best teacher; but even the best of us often has to tackle a new job. A fellow who has never learned to swim and who falls overboard has three alternatives: (1) give up and drown, (2) to be rescued, or (3) strike out for himself. The plant operator must not give up, he must strike out for himself. Nobody is going to rescue him. He can avail himself of aids to save himself even if some prove to be only straws. And although much about plant operation will have to be worked out anew, much can be learned by attending meetings such as these and by reading about the accomplishment of others in current literature.

Mr. Emigh told me that his operators crave for literature and printed material to read and study, so that they may learn the "why" and "wherefore" of what goes on around the plant.

Unfortunately many of our best operators never write down their troubles or results for publication—would that they did!

The operator must first of all study his plant and be sure he knows every part and what each part is supposed to accomplish. Then he must understand how such accomplishment is to be brought about and all the conditions necessary for the correct results.

Finally, he must know how to make the proper tests to tell him when something is *beginning* to go wrong and when the results are *just right*.

Time will not permit me to review recent articles, but I mention and urge you to read the articles by Haseltine, Harris, Cockburn, Anderson, Theriault, McNamee, Grant, Hurwitz, Mohlman, and many others.

And above all, the Report on Sewage Research in the *Sewage Works Journal*, "A Critical Review of the Literature of 1936."

And now, Mr. Chairman, I suggest that the Program Committee arrange to have, each year at these meetings, a paper setting forth a critical review of the literature on sewage treatment and sewage works operation for the twelve months preceding.

# SEWER MAINTENANCE*

By Grant M. Olewiler

*Superintendent, Sanitary Drainage Department, Lower Merion Township*

*Q. 1. What is the nature and extent of the sewer system of Lower Merion Township?*

A. 1. The sanitary sewer system of Lower Merion Township consists of 119.89 miles of sewers serving a territory of about 12 square miles. This represents about 50 per cent of the area of the Township, but the system serves about 90 per cent of the population, which was 35,000 at the time of the 1930 census, and is now estimated at 40,000. Pipe is of vitrified clay or cast iron, with joints of cement or lead. Except for the intercepting sewers, the pipe is 8 in. inside diameter. Intercepting sewers vary from 10 to 24 in. There are slightly over 3,100 manholes in the system.

*Q. 2. What is the nature of the maintenance work on the sewer system?*

A. 2. Maintenance of the sewer system consists of: (1) flushing the entire system, progressively, once a year; (2) cleaning of sewers found to be flowing in a sluggish manner, or subject to root growth, by dragging; (3) setting manhole tops to new grades established by road construction or regrading of private property; (4) cleaning screen chambers and collecting wells at the sewage pumping stations; (5) replacing handles in manhole lids; (6) repairing and replacing buckets placed under ventilating lids to catch sand and road stone, which would otherwise enter the sewer in times of storm; (7) re-distributing ventilating lids to provide better ventilation for the system as well as to overcome complaints of odors; (8) placing asphaltic or asbestos gaskets under lids which have become noisy; (9) building channels where the old ones have become eroded or were not constructed properly; (10) removing stoppages and investigating reports of stoppages; (11) building new manholes where it is found that the interval between manholes is too great for proper maintenance; and (12) making general repairs or replacing pipe in places where the sewer has been broken by external forces.

*Q. 3. How is flushing accomplished and why is it necessary?*

A. 3. Flushing of the sewer system is accomplished by discharging the contents of a 625 gallon steel tank, mounted on a truck, directly into manholes through a six inch vertical gate valve. The water discharges so rapidly that it entirely fills the outlet pipe and provides a strong flow of water which will thoroughly

* Presented at "Sewage Works Clinic," Meeting of the Pennsylvania Sewage Works Association, June 22, 1937.

clean an 8 in. pipe of grease or other light sediment for a distance of from 500 to 800 feet, depending upon the grade of the pipe. As a minimum grade of .005 has been established and enforced for 8 in. pipe in this Township, and very few of the branch sewers have a depth of flow of more than 1½ in., the purpose of flushing is to remove a film which grows from the sides of the pipe, and other light sediment, rather than to clean the pipe of sand or stones, because they are taken out by dragging.

*Q. 4. What experience have you had in obtaining water for flushing, and what is the present cost of water?*

A. 4. Water for flushing was formerly purchased from a private water company, at a cost of 40 cents per thousand gallons, plus a standby charge of $85 per year for each point where a 2 in. water service was run to a manhole, to provide a place from which water could be obtained. Use of fire plugs, except at a high rate of charge, is prohibited. As the cost of water seemed out of reason, a gasoline-driven self priming pump with 2 in. suction hose was purchased at a cost of $195, placed on the truck, and connected with the tank. Water was then pumped from creeks in the various localities. This provided more places for obtaining water than were available from the five Water Company plugs, and cost less than half of former charges, even for the first year, when the cost of the pump was included. Since that time, the cost of the water, consisting of cost of gasoline, oil and grease, repairs and depreciation of pump, and new suction hose has been about $65 per year.

*Q. 5. What is the organization of the flushing crew?*

A. 5. The flushing crew is made up of one truck driver, one foreman, who has worked upon the system for about fifteen years and is thoroughly familiar with it, and one laborer to help open manhole lids, and observe flows.

*Q. 6. What plan is followed in this work?*

A. 6. Each watershed is taken separately. The branch line entering the trunk sewer nearest to the outlet is flushed first by emptying water into the dead end manhole, or such other manholes as the length of the line requires. The branch next higher is then flushed, and so on until the entire watershed has been covered. All manholes in the path of the flow from any point of discharge are first opened to inspect the condition of the channel, or any backing of sewage into the manhole, before water is emptied into the higher manhole. Experience has taught that this is essential because many sticks, stones and other materials that might lodge in the pipe have been found during this preliminary inspection, and were removed before the flow of water carried them on. The only exception to this procedure is in the case of the larger trunk sewers, where the distance between branches is so great that the truck would be held up

to await the arrival of the other men. These lines are patrolled upon completion of the flushing in each watershed. While the inspection is being made, the truck driver has gone to the nearest creek, filled the tank with water, and returned to the next manhole indicated by the foreman. This operation is then repeated until the system is flushed. Separate loads of water are not discharged into trunk sewers above 12 in. diameter, as the amount of water held in the tank and discharged through a 6 in. valve would not increase the depth of flow and velocity sufficiently to justify the operation, especially since the flows in the larger sewers have sufficient velocity to carry most of the material which gets into them, and also have the benefit of all the loads of water dumped into the branch sewers.

The original method of flushing was to begin at the highest point, and work down the sewer system. This was discarded in favor of working up the system, because of the two-fold washing effect where branches intercepted. While this choice may be with the Superintendent of Maintenance, the major requirement is to adopt a system, and follow it. Daily records are kept, showing the areas covered.

Q. 7. *What is the total cost of the work, and how does this compare with costs in the past?*

A. 7. The cost of flushing the system in 1936, was $693.09, itemized as follows:

| | |
|---|---|
| Wages of Men, 34½ Days | $400.20 |
| Supervision by Superintendent | 51.75 |
| Cost of Truck, Insurance, Depreciation, Gasoline, and Oil | 176.53 |
| Cost of Pumping, Repairs, Supplies and Depreciation on Pump | 64.61 |

This is equivalent to a cost of $5.89 per mile of sewer, and compares with $6.88 in 1935, $12.08 in 1932, and $18.95 in 1922, before pumping our own water.

Q. 8. *How is the inspection made, during flushing, of value for other work?*

A. 8. As flushing progresses, notes are made of sections of sewer where the water will not run off properly, manholes where the channels are in bad shape, or manholes which have been covered by grading. Any missing manhole lid handles, and those about to break, are replaced by new ones.

Q. 9. *How do you care for the flow while channels, found to be defective when inspected while flushing, are being rebuilt?*

A. 9. Upon completion of flushing, those channels which were found to need attention are reconstructed. In cases where the flow of sewage is small, sewage is kept away from the work by inserting expanding rubber plugs in the pipes entering the manhole until the new channel is formed, and then passing the flow over light sheet iron forms or over other material, until the cement-concrete has had a chance to harden. In cases where the normal flow is heavy, as in intercepting lines, it has been

found necessary to do this work between midnight and eight o'clock A.M., when the flow is only a small fraction of daytime volume.

*Q. 10. What work is done next?*

A. 10. Manhole tops covered, or exposed by grading operations, are then raised or lowered to conform to the new grades.

*Q. 11. Who raises or lowers the manhole tops when roads are being regraded and reconstructed, and what has been your experience with this work?*

A. 11. In order to insure the proper placing of manhole tops, the Sewer Department insists that all raising or lowering be done by our repair force. This procedure was established when inspection in connection with flushing showed that, when the work was done by road contractors, no care was taken in raising or lowering manhole tops, and the lids were raised on rough stone, or anything else that happened to be handy. As this material was not properly bound with cement, it was soon dislodged by traffic and fell into the sewer, not only providing causes for stoppages, but also causing the top to settle, with the result that the new roadway would have to be cut to raise the manhole top. In cases where the road was lowered, the new top of brickwork would come through the crown of the manhole, where the diameter was considerably larger than the inside of the manhole frame, with the result that the frame would only have a small bearing on brickwork, and that would be on the overhanging portion of the brick; some lids were found to have been suspended on reinforcing irons. Under construction by our own force, changes in height of more than several courses of brick make necessary tearing out of the crown, and rebuilding of the manhole wall. All changes are made with the use of brick masonry.

*Q. 12. What method have you adopted to exclude road material from the sewer while roads are being reconstructed?*

A. 12. When a road surface is to be reconstructed, the bottoms of the manholes are covered with boards to keep out as much debris as possible. This is necessary, because the first thing which happens is that the power shovel lifts the manhole top, together with other road surface, and into the manhole goes about half a yard of road surface, stone and dirt. If someone is there to enforce it, an attempt is made to clean out the manhole, but if it were not for the false bottom, a considerable quantity would go down the pipe. The frame is then replaced over the hole, not fastened, and as each of the line of trucks passes by, it is given a nudge, and more dirt goes to the bottom. When the road is ready to be sub-graded, the manholes are rebuilt to bring the top to the grade elevation, but again, unless a close watch is kept, trucks or graders will knock it off. The final danger is passed if you are successful in having the base course

rolled without moving the lid, where a two-course road is constructed, or get the concrete finishing machine past the manhole without moving the lid, or in some cases, where the inspector insists on finishing the road with the manhole lids removed, in keeping the concrete from entering the manhole. Upon completion of the paving, the false bottoms must be removed, together with as much of the debris as possible. The sewer line is then cleaned by dragging to insure a clean sewer, and to avoid telephone calls in the middle of the night, on Sunday or holidays, as it seems that a sewer can not become stopped, or rather reported, during working hours.

In one instance, before the present program was arranged, a stone 9½ in. wide, 3 in. thick, and 12 in. long had entered a 10 in. diameter sewer, and had moved down the line for a distance of 150 ft. before it lodged in such a position that it could not be moved by rodding the sewers. Needless to say, the pipe was uncovered and a section removed, in order to clear the line.

*Q. 13. I notice that you refer to cleaning screen chambers and collecting wells at the sewage pumping stations. Will you tell us about this?*

A. 13. The collecting well at each of the sewage pumping stations is provided with a screen and grit chamber to remove rags, large objects, and the grit or sand which would otherwise score the pump shafts and erode the impellers and pump casing. Rags and other material caught on the bar screen are removed by hand by the station engineer, and buried upon the property, and the sand pits are cleaned by the sewer repair force when they show evidence of filling. This is generally done twice a year. At the same time, the walls of the large collecting wells are scraped to remove grease. Material removed is buried on the station grounds, except at the Ardmore Pumping Station, where there is no land available, because of the closely built neighborhood, and it is therefore hauled to the Mill Creek Pumping Station, and buried in the large meadow adjoining this station.

*Q. 14. What type frame and cover is used, and what has been your experience with covers?*

A. 14. Manhole frames and covers are of cast iron. The frame is 7 in. high, and has a 24 in. diameter tapered opening in which the cover seats. The original type had a seat 1¼ in. deep with a corresponding thickness of the cover around the outer edge, while the center of the cover was reinforced by ribs, which made a thickness of 2½ in. in the center of the cover. Following the practice of the City of Philadelphia, a frame with a seat 3 in. deep, and a cover with a corresponding thickness around the outer edge, but without material change in the location and size of reinforcing ribs, was later substituted for the lighter top on all new work. This frame and cover weigh around 350 pounds.

Argument for the heavier lid was that the lighter cover would jump off, and break under the increased speed and weight of loads carried by the present day trucks. This does not seem to be justified by my experience in maintenance work, for the past fourteen years, as the only time that I had definite knowledge of a cover coming off was when one heavy type lid disappeared entirely, presumably being stolen. Several reports that lids were off were investigated immediately, but the lids were always in place when visited, while only three or four had cracked, and in each case, the road was found to have a rut, or hole, a short distance in front of the cover, so that the lid was subjected to an unusually severe impact, and it is doubtful if the heavier lid would have stood the strain. In the same period, one of the heavier lids cracked and had to be replaced.

*Q. 15. Do you favor the use of handles for manhole covers?*

A. 15. From the viewpoint of maintenance of the system, it is essential that the lids be provided with some means of lifting them in order to inspect and work on the sewer. Our experience is that two handles of ½ in. diameter iron, used in conjunction with an opening large enough to insert the end of a pick, cast into the outer edge of the cover, are very helpful, especially when the opening between the frame and cover has become filled with road asphalt or when the fit is tight. In some cases, the lids become so tight, that it is necessary to use the hoist on the truck to provide enough force to remove the lid, and I have seen places where the frame would lift the road surface before the cover would come off. Needless to say, in these cases steps are taken to make a looser fit before the cover is again replaced. In all cases of tight lids a generous use of a hammer seems to be of value. While this item may seem unworthy of much thought by the designing engineer, it is of extreme importance to the maintenance force and once a system is started, and the manhole covers set in road paving, it is an expensive proposition to replace the work.

*Q. 16. What is meant by "ventilating covers"—are they necessary?*

A. 16. Although any opening in the cover may admit water in time of storm, it has been found necessary to provide ventilation for the system, especially since the use of a main house trap located near the property line of the road, does not allow free ventilation through each house line. This ventilation is provided by placing eight 1 in. diameter openings in "Ventilating Covers." These covers are placed at dead ends of the system and roughly at each third manhole, although none is placed if the manhole is in a gutter, is so located that considerable storm water would flow over the cover, or if the manhole is located near a house, or in such other location that odors would become a nuisance to property owners. As additions are made to the sewer system, it becomes necessary to relocate the ventilating manholes.

*Q. 17. Does not a considerable quantity of road grit or sand enter the sewer when ventilating covers are used?*

A. 17. All frames are provided with pockets to support the legs of a bucket, which hangs under the ventilating cover, and catches any sand or road stones which would otherwise enter the sewer. The bucket also becomes a receptacle for sticks, pieces of wire and even umbrella ribs, which are pushed through the openings. These items, if allowed to enter small diameter sewers, would be a potential source of stoppage. Notations of buckets which require new hangers or other repairs are made while flushing and repairs are made when the other work will permit. This is generally done when the weather, because of cold or storm, will not permit outside work.

*Q. 18. What have you done about the noisy manhole lid problem, and cases where lids have a tendency to roam?*

A. 18. Until about a year ago, noisy manhole were made quiet by placing a layer of sand, mixed with road asphalt, on the seat of the frame and then placing the cover on this cushion. At present a prepared asbestos gasket, reinforced with brass wire and covered with an adhesive surface, is being tried with good results. In a few instances, manhole lids along the trunk sewers near creeks were found to have been removed, and rolled into the water. The lids were replaced but at later dates were again found to be removed. In order to prevent further removals, asphaltic compound, purchased for making joints in terra cotta pipe, was poured in the space between the frame and the cover. Since that time, the manhole lids were not disturbed, and it is even difficult for our own men who were accustomed to opening tight covers, to remove these lids. After that, the asphalt was only applied to three or four points around the cover, but was sufficiently strong to prevent removal of the lid by persons without tools.

*Q. 18a. What has been your experience with manhole steps?*

A. 18a. Manhole steps installed when the original sewers were constructed in 1904 were "U" shaped, and were staggered. In all later construction this type was abandoned in favor of bars placed to form a ladder, because of the tendency to slip from the step, especially when they became coated with the slimy deposit which forms in manholes. Prior to 1927, steps were built of galvanized iron pipe, but when some of these began to rust, the Township adopted a policy to purchase solid wrought iron, heavily galvanized bar steps, and to require that all contractors purchase these items from the Township so that the Township now retains control of the quality of the bars. The same policy was adopted for manhole frames and covers, and cast iron "Y" saddles used in making connections to sewers when no "Y" branch is available.

*Q. 19. What is your experience with the location and nature of stoppages?*

A. 19. Reports of stoppage in the sewer are investigated immediately and with few exceptions are found to be in the lateral or house connection which must be maintained by the property owner. The owner is then notified. When a stoppage in the main sewer is found, one man and rods are obtained from the sewer repair force, and the sewer is rodded. In a majority of cases, where sewage has backed into the manhole without evidence of a stoppage and overflow of a trap vent at a point lower than the manhole, it has been found to be a good policy to obtain a pipe or long pole, and be sure that there is no obstruction at the mouth of the outlet pipe, as most of our trouble has been located at this point. In one instance, a stick had lodged across the pipe, and the accumulation of rags, paper, etc., had sealed the outlet so that a head of 9 ft. was created. On several other occasions, someone had placed quantities of stones from nearby creek beds in the manhole, and thus shut off the outlet. While the general cause of stoppage is the entry and growth of tree roots in the sewer, other obstructions found were a large soup bone, a beer bottle, three croquet balls tightly wedged together, and not infrequently, roots torn loose from house connections by plumbers and allowed to go down the line in such volume that when they entered the main sewer they piled up, and shut off the flow. At one time, someone had removed a manhole cover and deposited in the manhole a small cartload of tin cans, ranging in size from a sardine can to a "Keebler" saltine can. By the time it was discovered the cans were strung out for about 900 ft. in a 10 in. diameter pipe and for several hundred feet in the 15 in. outfall line. The cans which had not entered the sewer were removed, and the entire line was dragged to the pumping station screen.

*Q. 20. Is it ever necessary to build new manholes on the older sewers?*

A. 20. When other work will permit, new manholes are constructed at points where the interval between manholes is too great to properly care for the sewer.

*Q. 21. What are classed as general repairs, and who makes them?*

A. 21. General repairs, including replacement of pipe found to be crushed, are also made by the three men comprising the sewer repair crew. Crushed pipes have been found to have been caused by backfilling of large stones directly upon the pipe, washing out of the base by a water pipe leak with a consequent settlement of the pipe and ditch, and settlement of a culvert wall.

*Q. 22. Do you ever have trouble with the force mains?*

A. 22. Occasional leaks develop in the lead joints on the pressure main from the pumping stations, generally because the joint is not caulked sufficiently hard to withstand the pressure, or, as in

the case of the original line laid in 1904, the pipe was not centered in the bell and straight pipe was used to turn bends. In two instances, cracked pipe developed. The pipes are uncovered and the joints recaulked, using cold lead in places where extra room develops in the joint. Where the pipe has become cracked, and a length or more must be removed, the Philadelphia Suburban Water Company has always come to the assistance of the Township, and loaned us their equipment, and men who are thoroughly familiar with the work. As might be expected, the leaky joints appear in the places most difficult of access, and generally on the bottom of the pipe—inspectors please note. At one time, a leak appeared on a creek bottom and, although the water could have been by-passed by the use of a flume, it would have required considerable time to construct the dam and flume. To save this time, the joint was caulked by a man who had to be completely submerged while working and had to come up for air at frequent intervals.

*Q. 23. What has been done toward cleaning the sewer system?*

A. 23. During 1928 the Township purchased a "Champion" sewer cleaning outfit, consisting of rods, buckets, cables and windlass, and hired men to operate it in cleaning the entire sanitary sewer system. Prior to that time, a truck and men were hired from a local contractor to flush the sewer system, clean the basins, and open stoppages whenever they occurred, but the Township did not have a full time force of its own. The first task was to locate and bring to grade the manholes which had been covered. It is estimated that in the first two years of operation of the sewer repair force, 700 manholes were uncovered and brought to grade. Because of the demands of the other work, it took five years to complete cleaning of all the sewers.

*Q. 24. What is the method used to clean sewers?*

A. 24. The method used is to push wooden, iron jointed rods between the manholes, fasten a cable to the end of the rods, and draw it to the next manhole by removing the rods. A bucket with jaws mounted on a swivel is then fastened to the cable, and drawn back and forth between the manholes, scraping any material in the pipe to a manhole, from which it is removed, until the bucket no longer brings out sediment. The operation is then repeated in the section next lower, until a trunk line is reached. All branches were carried down first, and then the trunk was cleaned. Since the system was cleaned, dragging has been confined to those sections which at the time of flushing are observed to flow poorly, and to streets where road construction has recently been completed. The wisdom of dragging these bad spots is reflected by the marked decrease in the number of serious stoppages, which before the sewers were cleaned seemed to be continuously occurring, and which now have de-

creased to the extent that a report of a stoppage is investigated before it is taken as a fact.

*Q. 25. Have efforts been made to reduce infiltration of ground water?*

A. 25. Some work has been done in efforts to locate and decrease infiltration of ground water, but the time that could be devoted to this work has been very limited. It is hoped that much more can be done in the next few years.

*Q. 26. What would you consider as maintenance of pumping stations?*

A. 26. Briefly, maintenance of the pumping stations consists of care of the buildings, pumps and grounds.

*Q. 27. What is done toward keeeping the buildings and grounds attractive?*

A. 27. The buildings are kept painted and cleaned while care is taken to have the grass, shrubbery, and flowers always kept in such a condition that the plants are the subject of favorable comment by the citizens. At two of the four stations, the grounds have been turned into parks for the public, and if the large number of persons who used them on Memorial Day is any indication of the coming use this summer, space will be at a premium.

*Q. 28. How can a small amount of inspection and work, keep pumps from losing their efficiency?*

A. 28. Volumes pumped by each unit are checked at frequent intervals, and the impellers and casings inspected for wear. Decreased pumping due to wear may be overcome to a large extent by setting the impeller on the shaft so that the space between the edge of the impeller, and the casing is reduced to a bare clearance.

*Q. 29. What about packing and oil?*

A. 29. Packing to be used to stop sewage from leaking out around the shaft is a matter of personal thought, and since I have not found two of our men who can agree on which kind is best, I will only mention the matter in passing. A sufficient supply of oil is important but, again, the particular brand which is best will be left to the opinion of the user, with the remark that although several standard makes have been tried, no one seemed superior.

*Q. 30. What is the chief source of trouble in operating the pumps?*

A. 30. Actual operation of the pump usually resolves itself into a battle between the operator and the rags or other solids which will stop the pump, especially when small size pumps with close impeller blades are in use. Of course, life is often interesting, as when thunder storms send flashes of electricity hopping from switchboards to radiators; when in the middle of the night a check valve refuses to close, with the result that the pump will not operate until the valve is taken apart and freed of rags, sticks or other material which has held it open; or when something stops the pump, and blows the fuses. It is then that one is thankful for duplicate units.

*Q. 31. Who supervises the construction of lateral conections to the sewer?*

A. 31. Until several years ago, the inspection of the sewer connection between the building and the fence line or property line of the road was made by the plumbing inspector working for the Board o fHealth, while the part of the line between the fence line and the main sewer was built by contract by the Township, and inspected by the Sewer Department. This arrangement was then changed so that now the Sewer Department inspects the entire connection from the sanitary sewer to a point ten feet from the walls of the building, which point is the end of the cast iron soil pipe laid by the plumber.

*Q. 32. Why was the change made?*

A. 32. This change was made so that the entire line could be checked for grade by a level instrument, and so that better location records could be kept, in addition to bringing the control of ground water infiltration into the connections, within the department which was most vitally interested in keeping this to a minimum. In addition to the change of jurisdiction, arrangements were made to refuse a plumber a plumbing plan until the connection was laid to the building.

*Q. 33. Were any good results accomplished?*

A. 33. Detailed location sketches are now made and placed on file. Plumbers are learning that the centering of the spigot end of the pipe within the bell is essential if they desire to lay the line with a hand level. Houses are no longer being connected where the fall from the building to the end of the lateral was extremely small and sometimes a negative quantity, because the plumbing inspector did not have equipment to check the total fall and had to depend on a level placed on each pipe. Builders are learning that they must place the building sufficiently high to have the necessary fall, and since the connection must be made before the house has progressed very far, they can no longer avail themselves of the plea that the work in the house has been completed and to make changes would involve tremendous expense, thus bringing sympathetic pressure to bear to have poor connections accepted. Use of cast iron pipe in wet places has been insisted upon, with a consequent reduction in the amount of infiltration.

*Q. 34. All sewers have a gradient, and therefore sewage must flow to the outlet, so why bother with all the many items of maintenance work which have been mentioned, especially since it all means an outlay of money for something which is under the ground, and therefore unseen, and unheeded by the majority of citizens?*

A. 34. It is indeed true that as long as sewers function properly, they are unseen and unheeded, but as soon as they fail to carry off the wastes from the buildings, they become very evident to those persons who are affected, and loud and vigorous protests

are voiced into the ears of those who control the government. After receiving several indignant telephone calls in the middle of the night, most elected representatives of the people are quite willing to make it their business to see that at least sewers in their districts are cared for properly. It is then that the neglect of maintenance is most evident. An unskilled working force must be organized, tools must be obtained, buried manholes and lines without recorded locations must be found before relief work may be started, and in the meanwhile, the insistent demand for action becomes more loud, and even insulting. Finally, when the stoppage has been located and removed, there is still the question of liability for damages to property, and the ever present fear of spread of contagious diseases, together with the expense of cleaning the mess which has resulted. Is it not far better to keep a few men who become familiar with the location of the lines, and skilled in the use of the tools, who can work on the sections known to be in need of cleaning, and thus reduce the chance of stoppage to a point where a stoppage is an accident, rather than to face the demands of citizens who believed that the funds which they pay as taxes entitle them to protection from these troubles. The big job is to make the citizens sewer conscious, and they will be ready to support the work if they can be shown the need. This is one of the real reasons for the adoption of a sewer rental which will not only provide sufficient funds, but will bring to the attention of the citizens the manner in which their payments are returned to them as benefits.

## Discussion

Chairman Freeburn: I think Mr. Olewiler has pretty well covered the subject, but if there are any questions we will hear from a few people very briefly.

Prof. O'Donnell: Do you have in your plumbing requirements the main drain trap?

Mr. Olewiler: Yes.

Prof. O'Donnell: That is still a part of your Board of Health requirements?

Mr. Olewiler: Yes.

Chairman Freeburn: Anybody else have anything to say? Of course nobody has any trouble with the sewer system!

Mr. A. F. Stone (Reading, Pa.): You mentioned in connection with the maintenance at the pumping station, that so far as the efficiency of the pumps is concerned, you move the impeller and the impeller shaft up to the impeller head to have the clearance between the impeller hub and the impeller head at a minimum. There are certain limitations as to how far you can move the impeller towards the impeller head, and after you have gone to the limit what do you do?

Mr. Olewiler: Buy a new one.

MR. STONE: The reason I asked that question, is that we have been repairing our pumps by putting a bronze ring on the impeller hub and a steel ring in the impeller head. We have a capacity of 11,000,000 gallons per day at Reading and we find that it works satisfactorily.

MR. OLEWILER: We have found that the cost of the impeller is not too high. Of course you are limited to one type of impeller. There is an open and closed type, and you can only do that on the open type.

MR. STONE: We have the open type impeller and it costs us around $60 per pump. So far as getting a new impeller is concerned, you would have to get a new casing. The cost of the installation of the brass and steel rings is about $60 per pump.

# MARCY STATE HOSPITAL SEWAGE TREATMENT WORKS*

By Henry Ryon

*Senior Sanitary Engineer, State Dept. of Pub. Works, Albany*

## The Old Sewage Treatment Works

The Marcy State Hospital, originally the Marcy Division of the Utica State Hospital, was built as a branch of the main hospital about 1921. The new buildings had a capacity of about 1,000 patients and employees, and the sewerage system and sewage treatment works were designed for that population and the installation completed about the same time as the buildings.

From the available records, it appears that the designers used as a basis for their computations an average sewage flow of 100 gallons per capita per day and a maximum rate of flow of 250 gallons. This is, of course, the generally accepted basis for the design of sewage treatment works for municipalities, but is not applicable to sewage works for institutions. The average sewage flow from the institutions of this state is about 175 gallons per capita per day and at about 25 per cent of the institutions the flow exceeds 200 gallons. The maximum rate of flow is usually between 2½ and 3 times the average, although in a few cases maxima of 4 times the average have been recorded. These high flows are not due entirely to dilution for the total solids in the sewage of the institutions of this state, from such records as are available, vary from 300 to 600 p.p.m., the B.O.D. from 200 to 300 p.p.m., and the settleable solids from 2 to 19 cc. per liter, the average for April of this year being 8.1 cc. per liter. Fortunately, the designers were in most cases very liberal in applying their basic rate of flow, using a detention period of 3½ hours in the two-story tanks and a rate of only 150,000 gallons per acre per foot of depth per day for the sprinkling filter. In designing some of the other units, however, they were not so liberal as is shown in the appended table giving the sizes and capacities of the different parts of the old sewage treatment works.

## Difficulties of Operation

About five or six years after the old sewage treatment plant was put in operation a proposition to construct new buildings at the institution that would increase the population to over 3,000 again drew attention to the matter of sewerage and sewage disposal.

The existing sewers were laid with cement mortar joints in trenches in shale rock and the trenches backfilled with broken shale. While there were only about 2½ miles of sewers varying from 6 to 15 inches in size, the infiltration after heavy rains amounted to about 400,000

* Presented at the Spring Meeting of the New York State Sewage Works Association, Utica, June 3, 4, 5, 1937.

gallons per day in addition to the flow of sanitary sewage, which averaged about 150,000 gallons per day. This of course flooded the treatment plant and decreased its efficiency. An investigation of the sewers indicated that the infiltration was about equally divided along the lines and could not be effectively eliminated without relaying the entire system. It was considered impossible to secure money for this purpose, and attention was turned to arranging the works to pass this excessive flow even though it might reduce the effectiveness of the treatment during wet periods.

The entire plant should without question have been remodeled and enlarged, but since insufficient funds for this purpose were available at the time, a temporary expedient was used. The two-story tanks would undoubtedly pass the high flows, although the removal of solids might be decreased at such times, but the dosing tank and sprinkling filter would not do so. A long overflow weir was therefore constructed in the dosing chamber to allow the excess flow above the capacity of the filter to pass through a new outfall line directly to the chlorine contact tank. The weir and bypass sewer were constructed in 1928. After this modification the normal dry weather flow passed through the plant in the usual manner but the excess storm flow found its way to the river with only tank treatment and chlorination.

A sewage treatment plant for the sewage contributed by a population of 1,000 persons, even though liberally designed, was obviously too small for the flow contributed by 3,000 persons, particularly when a large amount of infiltration was added to the normal flow. It was accordingly recomended that the entire plant be remodeled and enlarged as soon as funds could be obtained. Such funds were made available in 1936.

The studies, begun before the money was made available, to determine exactly what changes and enlargements should be made at the plant brought out some interesting and curious facts. Experience with two-story settling tanks at the state institutions had seemed to indicate that tanks of this type were not entirely satisfactory for institutional sewage because of its high grease content, which in many cases caused nearly all of the solids to rise to the top instead of settling. When this fact was mentioned to the designers of the original plant they immediately took the opposite view and mentioned the Marcy tanks as giving exceptionally good results. A visit to the Marcy tanks followed. The flowing-through compartments of the two-story tanks were found to be covered with a heavy scum and the gas vents entirely free. The reason for this unusual condition was explained by the man at that time in charge of the plant. He had been instructed, he said, when the plant was installed, to skim the gas vents daily and throw the scum into the flowing-through compartments, and had been doing so for several years. He seemed rather skeptical when the proper method of operation was explained to him and referred to the method of operation at a plant in a suburb of Utica. The plant referred to had, at that time, circular Imhoff tanks with wooden baffles and the operator had cut

away the baffles between the gas vents and the outlet channels with the result that no scum accumulated in the gas vents.

After the visit, the method of operation was changed. A heavy scum then accumulated in the gas vents which the operator seemed unable to cause to sink either by stirring or by the use of lime. Very little sludge accumulated in the bottoms of the tanks and the only way to remove the solids seemed to be to dip them out of the gas vents, a very laborious process. Mr. Rounds, the present chief engineer, later devised a rather unique labor saving device for removing the scum. A rectangular steel bucket just wide enough to enter the gas vents and having a capacity of about 5 cu. ft. was built and attached to a steam engine operated crane with a boom long enough to reach all the gas vents. By the use of this crane and bucket it has been possible to remove the scum from the tanks very rapidly. The solids removed are, however, not well digested and do not dry readily on the sludge bed.

Another characteristic of institutional sewage, which adds to the difficulty of operation at this plant as well as at most other institutional sewage treatment plants, is the large number of rags that it contains. These rags include not only torn pieces of cloth which are worthless but also many towels, suits of underwear, pillow cases, handkerchiefs and similar articles which can be salvaged. Over 100 articles of this kind are often sent back to the laundry in one week at some plants. This fact has led the superintendents of some institutions to object to the use of shredders in connection with the automatically cleaned screens.

Another condition at the old plant which may be of some interest, although it causes no trouble, is the presence of snails in the sprinkling filter. The presence of these small snails in the filter beds at the Rome State School and the Rockland State Hospital was mentioned at the Geneva meeting last October (*Sewage Works Journal*, January 1937, page 89). At these two plants the snails appear to remove the growths on the stone and prevent pooling without producing any detrimental effect on the efficiency of the beds. At Marcy, however, the snails are seldom found in the upper foot of the bed although they are very numerous lower down, and large quantities of shells can be seen in the final settling tank.

## The New Sewage Treatment Works

In designing the new sewage treatment works, now under construction, for the Marcy State Hospital, an attempt has been made not only to provide for the excessive rate of sewage flow and a reasonable increase in population, but also to eliminate as far as possible the present operating difficulties. Although the present population is only about 3,300 and the maximum recorded sewage flow only about 1,500,000, the plant has been designed for a future population of 5,000 and a maximum rate of sewage flow of 2,500,000 gallons per day. An automatically cleaned screen has been provided for removing rags and other large solids. No grinder is to be installed, however, and the

solids will be deposited on a draining platform so as to allow them to be sorted and the usable rags salvaged. The present two-story tanks are to be abandoned and clarifiers and digesters submitted. These clarifiers are to be equipped with skimmers, by means of which the grease and other floating solids may be removed and pumped to the digesters, where experience indicates they can be reduced to a condition suitable for satisfactory drying on the sludge bed. The filtering capacity is to be doubled by the addition of a second filter and a new glass-covered sludge bed is to be installed in place of the original open bed. Chlorination equipment for both pre and post chlorination is to be provided. The only part of the old plant which will be retained and incorporated in the new plant is the present sprinkling filter on which the sprinkler heads will be changed to operate more satisfactorily with its new dosing tank. A detailed statement of the sizes and capacities of the different units of the new plant is given in the appended table.

It is not expected that any serious problems will be encountered by the contractor in the construction of the new plant other than the usual one on such reconstruction work of building the new units and placing them in operation without interrupting the operation of the existing ones.

MARCY STATE HOSPITAL

*Old Sewage Treatment Works*

| | |
|---|---|
| Date of construction | 1920–1921 |
| Population at hospital, 1920 | 1,000 |
| Design capacity: | |
| Population | 1,000 |
| Sewage flow (average) | 100,000 g.p.d. |
| Sewage flow (max. hourly) | 250,000 g.p.d. |
| Inlet sewer: | |
| Size | 15 in. |
| Capacity | 2,500,000 g.p.d. |
| Screens: | |
| Number | 2 |
| Width of chambers (each) | 3 ft. 8 in. |
| Bars 2 in. by ½ in. spaced | 1 in. apart |
| Settling tanks (two-story): | |
| Number | 2 |
| Size (each) | 29 ft. 4 in. by 14 ft. |
| Depth (below flow line) | 24 ft. 6 in. |
| Gas vents (width) | 18 in. |
| Baffles lapped, slots | 6 in. |
| Settling compartments: | |
| Capacity (both) | 36,500 gal. |
| Detention period (design capacity average) | 8.7 hr. |
| Detention period (design capacity max.) | 3.5 hr. |
| Sludge compartments: | |
| Capacity (both) | 4,180 cu. ft. |
| Capacity per capita (design capacity) | 4.2 cu. ft. |
| Sludge bed (open): | |
| Area (39 ft. 6 in. by 39 ft. 6 in.) | 1,560 sq. ft. |
| Area per capita (design capacity) | 1.6 sq. ft. |

Sprinkling filter:
- Area (98 ft. by 110 ft.) ..... 0.25 acres
- Depth ..... 6 ft. 9 in.
- Rate (design capacity, average) ..... 60,000 gal. acre day per ft. depth
- Rate (design capacity, max.) ..... 150,000 gal. acre day per ft. depth

Final settling tank (two-story):
- Size ..... 12 ft. 4 in. by 26 ft.
- Depth below flow line ..... 20 ft.
- Settling compartment:
  - Capacity ..... 12,500 gal.
  - Detention period (average) ..... 3 hr.
  - Detention period (max. flow) ..... 1.2 hr.
- Sludge compartment:
  - Capacity ..... 2,000 cu. ft.
  - Capacity per capita ..... 2 cu. ft.

Sludge bed (final tank)
- Area (24 ft. by 24 ft.) ..... 574 sq. ft.
- Area per capita (design capacity) ..... 0.6 sq. ft.

Chlorination:
- Applied to final tank effluent.
- Mixing and contact tank under floor of chlorination house.
- Size contact tank ..... 16 ft. by 12 ft.
- Depth ..... 2 ft. 3 in.
- Capacity ..... 3000 gal.
- Detention period (design capacity, average) ..... 43 min.
- Detention period (design capacity, max.) ..... 17 min.

The above figures are for an average sewage flow of 100 gallons per capita per day used as a basis of design for this plant. The actual average flow of sewage at the institution is between 150 and 200 gallons per capita per day. The actual rates are therefore nearly double those given and the detention periods about one-half those given.

*New Sewage Treatment Works*

Date of construction ..... 1937
Population at hospital 1937 ..... 3,300
Design capacity:
- Population ..... 5,000
- Sewage flow (average) ..... 1,000,000 g.p.d.
- Sewage flow (maximum hourly rate) ..... 2,500,000 g.p.d.

Inlet sewer:
- Size ..... 15 in.
- Capacity ..... 2,500,000 g.p.d.

Screen, automatically cleaned:
- Width of channel ..... 3 ft.
- Bars $\frac{3}{8}$ in. by 3 in. spaced ..... 1 in. apart

Measuring weir:
- Rectangular, sharp edge, length ..... 6 in.
- Automatic recording gauge.

Primary clarifiers:
- Number ..... 2
- Straight line type with skimmers.
- Size (each) ..... 50 ft. 9 in. by 16 ft.
- Depth ..... 7 ft. to 7 ft. 6 in.
- Capacity (both) ..... 88,000 gal.
- Detention period (design flow average) ..... 2.1 hr.

Sludge pumps:
- Number ..... 2
- Size (single cylinder, single acting) ..... 10 in. by 5 in.
- Capacity (each) ..... 15 to 70 g.p.m.

Digesters:
- Number ..... 2
- Size ..... Diameter 26 ft.
  Depth 17 ft
- Capacity (both) ..... 18,000 cu. ft
- Capacity per capita (both, design pop.) ..... 3.6 cu. ft

Digesters equipped with stirrers and gas collection devices, heated.

Sludge bed (glass covered)
- Size ..... 102 ft. by 50 ft.
- Area ..... 5,100 sq. ft.
- Area per capita (design population) ..... 1.1 sq. ft.

Dosing tanks:
- Number, one for each filter ..... 2
- Capacity (each) ..... 7,000 gal.
- Size of siphons ..... 14 in.

Sprinkling filters:
- Number ..... 2
- Size, one (old) ..... 98 ft. by 110 ft.
  one (new) ..... 98 ft. by 111 ft.
- Depth ..... 6 ft. 9 in.
- Area (both) ..... 0.5 acre
- Rate (design flow, average) ..... 300,000 gal. acre day per ft. depth

Final settling tank (clarifier):
- Size ..... 50 ft. 9 in. by 16 ft.
- Capacity ..... 44,000 gal.
- Detention period ..... 1 hr.

The design is the same as primary clarifiers except that there are no skimmers.

The sluge is pumped to the digesters.

Chlorination:

Duplicate solution feed chlorinaters in the pump house are arranged to apply chlorine to the screen chamber and also at the filter outlet ahead of the final settling tank.

Contract price ..... $155,459.50

(The sprinkling filter is the only portion of the old works retained and incorporated in the new works.)

# Operators' Reports and Suggestions

W. D. Hatfield
219 Linden Place
Decatur, Illinois

## MICHIGAN SEWAGE WORKS ASSOCIATION

Thirteenth Annual Conference, East Lansing, March 31–April 2, 1937

### Round Table

During the Round Table, the Conference was divided into groups with leaders appointed to conduct discussions on the subjects designated. These leaders then reported the discussions in the general meeting.

The subjects designated for the various groups were: (1) Sludge treatment and disposal; (2) Sewage filters; and (3) Activated sludge. The following abstracts were taken from the leaders' reports.

#### Sludge Treatment and Disposal

*Question:* How may the digestion period of solids in a digester be determined?

Suggestions: (1) The time for the complete turnover of the tank by the raw sludge additions might be considered as the digestion period. (2) The time for the complete turnover of the tank based on digested sludge withdrawals. (3) Average pounds of solids in the tank divided by the average pounds of solids withdrawn. (4) The average volume of sludge below the supernatant liquor level divided by the average volume of digested sludge withdrawn with possibly a correction for the concentration of the sludge.

Conclusions: There are so many variables due to supernatant liquor withdrawals, volatile solids reductions and concentration of the sludge that an accurate measure of actual average digestion time is difficult.

*Question:* What solids concentration might be expected in a *good* supernatant liquor?

Conclusion: About 0.5 per cent or less.

*Question:* What about pH adjustment in control of foaming?

Conclusion: The pH test does not tell the story. A quantitative determination of alkalinity is necessary. Foaming never occurs when the methyl orange alkalinity is above 1,500 p.p.m.

*Question:* How should a new digester be started?

Conclusion: (1) Liming is only a temporary measure. (2) Fill digester with sewage, heat to 85 or 90 degrees F., add raw sludge slowly until digestion starts, then increase raw sludge additions.

*Question:* What is the effect of any great variation in digester temperature?

Conclusion: The process of digestion is interrupted causing a decrease in gas production and an increase in the solids content of the supernatant.

*Question:* What difference in bacterial flora is likely during acid digestion?

Suggestion: During the acid stage acid-producing bacteria are prevalent and as food for these bacteria is used up, the alkaline producers take control. If raw sludge is added at too high a rate, the food supply for the acid producers increases sufficiently to give them control resulting in a lower pH value.

Conclusions: Due to lack of knowledge of bacteriology, the group was unable to draw any conclusions on the question.

*Question:* How may digested or undigested sludge be best disposed of?

Suggestions: (1) If the sludge is to be used for fill or as a fertilizer it should first be digested. (2) Local market governs the use of the sludge as a fertilizer. (3) Vacuum filtration and incineration is the best method of disposal for undigested sludge.

### Sewage Filtration

*Question:* What methods are employed in the control of the filter fly?

Answers: (1) Treatment with di-chlor benzene at the State Prison plant at Jackson. (2) Flooding of the filter at Pontiac. (3) Removing a filter from service for several days. (4) Chlorination to a residual.

*Question:* How do the results of a trickling filter compare with those from the activated sludge process? How do the two processes compare?

Suggestions: (1) The trickling filter is more reliable particularly where an industrial waste is combined with the domestic sewage. (2) Trickling filters can operate under a greater range of loadings and still produce a stable effluent. (3) The activated sludge process is capable of producing lower effluent B.O.D.'s and a higher degree of stability than the average trickling filter.

*Question:* How may odors about a trickling filter be controlled?

Suggestion: Chlorination of the filter influent.

### Activated Sludge

*Question:* Does over-aeration cause bulking?

Conclusion: It does not. One plant makes the practice of treating only a portion of the flow during periods of bulking, thus getting their floc back into good condition.

*Question:* How much material is actually burned up due to wet combustion in the aeration process?

Conclusion: No definite answer was arrived at.

*Question:* What is the advantage in tapered aeration in a diffused air plant?

Conclusion: Since less than 10 per cent of the air is used for actual oxidation and the balance for keeping the mixed liquor in motion, very little could be saved by varying the quantity of air through the different parts of the aeration unit.

*Question:* Is the Odeeometer necessary for the average activated sludge plant in order to determine the amount of air required?

Conclusion: The Odeeometer, considering the money invested, is not a necessity since by taking the dissolved oxygen content of the mixed liquor through the aeration tanks, satisfactory results and economical operation may be obtained.

*Question:* What dissolved oxygen content should be carried in the mixed liquor?

Conclusion: From 2 to 5 p.p.m.

*Question:* When would it be advisable to use colloidal treatment and when nitrifying treatment?

Suggestions: (1) Colloidal treatment only would usually be suitable during the winter months and possibly during the entire year when sufficient diluting water is available. (2) Nitrifying treatment requires about 40 per cent more air. (3) A higher solids content in the mixed liquor is also necessary if the treatment is to be carried to the nitrifying stage.

*Question:* What solids contents are carried in the various plants represented by the group?

Answers: (1) Escanaba, 4,000 p.p.m. (2) Howell, 1,000 to 1,500 p.p.m. (3) Muskegon Heights, 2,000 p.p.m. Plants using mechanical aeration can carry a lower solids content in the mixed liquor.

*Question:* What sludge blanket should be carried in the final tank?

Conclusion: Not more than 2 feet.

*Question:* How rapidly does the sludge in the secondary tank become septic?

Answers: Escanaba: During the summer, about 2 hours after shut down a septic sludge was indicated; Jackson: About 12 hours during winter operation.

# OHIO CONFERENCE ON SEWAGE TREATMENT

## Tenth Annual Conference, Columbus, Oct. 1–2, 1936

## EXCERPTS FROM GROUP DISCUSSIONS

### ACTIVATED SLUDGE

Discussion Led and Reported by E. E. Smith *

The two Ohio activated sludge plants represented, Elyria and Lima, reported that in their operations reasonably good removals are accomplished. Mr. Collier (Elyria) stated that his primary tanks remove 60 per cent of the suspended solids and about 40 per cent of the B.O.D.; Mr. Prentice (Lima) remarked that at Lima these respective removals by primary sedimentation are 55 per cent to 60 per cent and 35 per cent to 40 per cent. Milton Spiegel, representative of the Chicago Pump Company, stated that at Flora, Ill., primary sedimentation on a very concentrated sewage (5-day B.O.D. of crude sewage, 570 p.p.m.) removes lesser amounts perhaps of the above constituents, 40 per cent to 50 per cent suspended solids and 35 per cent B.O.D. and indicated that most satisfactory results are being obtained on the influent of high organic content by the activated sludge type of treatment.

In answer to a question relative to the percentage of activated sludge in the influent of the aeration units, Collier stated that in his opinion this is governed by an optimum suspended solids content in the mixed liquor. At his plant this is about 5,000 p.p.m. which by rough measurement is represented approximately by 20 per cent by volume settling in an Imhoff cone over a period of thirty minutes.

Stage or tapered aeration which has gained much favor among sanitary engineers seems logical and further seems to be basically the scientific attack in controlling the activated sludge process and in rendering it not only more efficient but also more economical. The greatest amount of air is needed in the critical first stage to take care of intermittent heavy organic loads, whether these be due to variable sewage concentrations, to stale sewage, or, to digestion tank supernatant or excess sludge discharged to the primary treatment units.

The value of the Odeeometer was discussed by Enslow and Spiegel. This laboratory device undoubtedly has value in the control of activated sludge treatment, particularly in large installations. However, Enslow was of the opinion that the dissolved oxygen in the aeration and final tanks is one of the best indications of proper plant operation. The plant is an Odeeometer in itself. Reference was made to the results that have been obtained at Rockville Center, N. Y., in which control of solids in aeration tanks has been worked out on the basis of dissolved oxygen maintained at various points through the units. This results in a form of stage aeration to meet requirements. The D.O. results furnished guidance in the limiting of returned sludge to meet air capacity limitations. Prolonged records of D.O. contents enables the operator to work out a program for meeting daily or seasonal requirements. At Lima the application of air is governed by the dissolved oxygen in the final tanks. An endeavor is made to maintain this content within 75 per cent of saturation. It was reported that at Elyria oxygen saturation of the final effluent is obtained practically all the time. This may be explained first by the fact that the present sewage load is considerably under the designed plant capacity, and second, by the fact that the air compressor equipment is not sufficiently flexible to reduce with economy the rate of air application in proportion to the sewage loads received.

Disposal of supernatant liquor from sludge digestion tanks presents one of the major problems at an activated sludge plant. Our discussion brought out that supernatant liquor, if returned through the plant, may better be applied gradually and directly to the aeration units than to primary settling tanks; that sludge digestion is simplified by stage digestion resulting probably in a less difficult supernatant; and that

* Superintendent, Division of Water and Sewage Disposal, Lima, Ohio.

concentration of excess sludge discharged to the digestion units may materially reduce the volume of the liquor. The centrifuge for concentrating excess activated sludge probably has possibilities. Other possibilities for the disposal of supernatant liquor are chemical treatment to condition it for dewatering on sand beds and lagooning where area is available. From the standpoint of the sanitary engineer, it would seem, however, that the latter particularly may be considered an expedient rather than a satisfactory solution of the disposal problem.

## SEWAGE FILTRATION

Discussion Led and Reported by M. W. Tatlock *

On opening this group meeting, the question arose as to features of the trickling filters being built at Dayton. The filter floor and ventilating system differs from the conventional in that the increment parts are being manufactured on the site of the works, using concrete as the material. Pyramids are poured on top of the floor proper. These are placed perpendicular to a drainage channel along one diameter of the filter. Precast concrete block 3⅝ in. by 2 in. by 21 in. are made and laid edgewise across the troughs staggering them so that over the troughs there are openings 2 in. wide by 18 in. long.

A question with reference to the feasibility of using forced ventilation was answered as follows: It is felt that if air is forced through the filter it will follow the line of least resistance, penetrating the unclogged area and leaving the loaded or clogged area, if there be such, in the same inactive condition.

It was reported that knowledge is had of an experiment where filter enclosures offered the opportunity to operate one under closed conditions and one in parallel under conditions free and open to the air. No difference in efficiency was noted but it was observed that the stone of the filter in the closed space was cleaner than that in the open filter. Housing of trickling filters under glass covers for controlling temperature during the winter months and for discouraging fly breeding during summer months possibly gives some promise.

With regard to filter medium, that which has been selected for Dayton is slag. However, discussion brought out the fact that limestone of an inferior quality may be used successfully if covered with a durable frost-resisting material to a sufficient depth on top. The proper depth of the durable material is probably dependent on geographic location and climatic conditions. Fretter (Medina) reported that pyrometer tests at depths of 6 in., 12 in. and 18 in. revealed that after four or five days cold weather the filter was frozen to a depth of 6 in. and remained so until the frost was out of the ground. It is probable that in this climate a thickness of durable material of 18 in. is satisfactory.

Hall, Norwalk, referred to the enormous load contributed to his trickling filters by corn canning waste. This waste is always concentrated but the concentration varies with the kind of corn canned and with changes in operation at the canning plant. All canning waste at Norwalk receives fine screen treatment at the source. The screened waste from the canning of the "Country Gentleman" brand has a 5-day B.O.D. of 1,000 to 1,200 p.p.m., whereas that from the canning of the "Golden Bantam" brand has a 5-day B.O.D. of 2,200 to 2,600 p.p.m. Waste from the ensilage pile has a 5-day B.O.D. content of 65,000 to 75,000 p.p.m and can not be admitted to the sewage treatment plant, its disposal being a problem of the canning company. He added further that although corn waste is a seasonal contribution, possibly eight to ten weeks during the late summer and early fall months, practically the entire organic load is borne by the trickling filters, severely taxing them and presenting a difficult problem which may reasonably result in further preliminary treatment of the waste before admitting it to the sewage treatment works.

In connection with the subject of the effect of industrial waste on trickling filters, Fretter reported that waste contributed by a pickle canning plant at Medina killed both

* Superintendent, Sewage Treatment Works, Dayton, Ohio.

the filter flies and the worms normally propogating in the filter but that it did not have any apparent effect on the efficiency of the unit, the degree of sewage modification being as satisfactory with the worms present as without them. It did curtail the supply of worms normally furnished to fishermen.

With reference to the question as to the advisability of the preaeration of sewage before filtration, little experience could be reported by those in attendance. Calvert of Indianapolis, however, advanced the thought that, if something had to be done to relieve the overloaded condition of trickling filters or probably to care for a seasonal heavy load, this feature might well be installed as an adjunct to existing plant equipment quickly and with economy to the municipality as a corrective measure.

The quantity of final tank sludge, as compared with the suspended solids in the sewage applied to trickling filters, and satisfactory methods of disposal, present problems at sewage plants of this type concerning which there is much disagreement. At the Dayton experimental plant, data indicate that of 90 p.p.m. of suspended solids applied 30 p.p.m. can be accounted for as humus sludge and 15 p.p.m. as suspended solids in the effluent. Records over eleven years at Marion indicate that for 100 p.p.m. suspended solids applied, 18 p.p.m. have been removed as humus sludge. Accounting of solids is a difficult matter and one that can be given much attention by the sewage plant operator and sanitary chemist.

In this whole question of operation of sewage filters and the performance that may be obtained from them, there is a remarkable lack of comprehensive data. The final action of the group was to request that this subject be recommended for assignment to a special committee for study and research during the next year and for report at our 1937 Conference.

## PRIMARY SEDIMENTATION AND SLUDGE DIGESTION

Discussion Led and Reported by R. A. Allton *

In a round table discussion of this kind, the greatest benefit is obtained by disclosing the difficulties that have been experienced in operating and in maintaining equipment features which have been designed to perform particular functions in sewage treatment works.

Sedimentation and sludge digestion were taken up in that order. It was generally agreed by the group that considerable effort is yet warranted in improving inlet devices to sedimentation units in order to obtain satisfactory distribution of sewage through the units and hence increase efficiencies of settling. It is also likely that at a great many plants much can be accomplished by the operating personnel toward obtaining more uniform sewage flows.

Under the subheading of sludge digestion, considerable discussion was had relative to tank insulation. It was reported that one digestion tank installation in this state presents difficulties in operation during winter conditions. Constant temperatures are hard to maintain. This unit is provided with a floating cover which is not insulated. It is likely that considerable heat is lost through the space between the cover and the structure walls so that very probably insulation of the digestion tank cover is rather important.

In discussing the measurement of gas from processes of sludge digestion it was stated that some meters which had been placed in service lasted for only about a year. Now, however, most manufacturers are using special corrosion-resisting materials in their meters with much better results. It seemed to be the consensus of the group that the displacement type of meter is favored and further that the bellows type is to be preferred over the positive displacement type.

Adequate ventilation of chambers about sludge digestion equipment and the elimination of pockets for the collection of gases was given attention in our discussion. The need for giving careful attention to this feature in the design of sewage works is self-evident. Frequently, forced ventilation is necessary.

* Sewage Disposal Engineer, Columbus, Ohio.

Corrosion of metals about sludge digestion tanks was a subject which seemed to hold considerable interest for the group. Aluminum heating coils completely corroded in a period of less than a year. At one installation, in Michigan, copper tubing is being used for this purpose. Nelson stated that experience in the West with coils of this material had been very gratifying. Copper coils have given satisfactory service for a number of years. It seems that copper tubing for heating coils may well be recommended. This tubing can be gotten in long lengths, can be placed easily in spiral form suitable for sludge digestion units and the connections for it are simple.

Further, in connection with the corrosion of metals, Brown, Marion, cited the results of an experiment made on samples of cast iron, Tungsten iron, wrought iron and steel. Of these, cast iron and Tungsten iron showed the greatest resistance to corrosion when subjected for a relatively long period to gases produced in an Imhoff tank.

Corrosion of metals about sewage works presents an interesting field for research. This problem has by no means been solved. Operators can be of much assistance if they will undertake experimentation of this nature. It requires little effort to subject samples of metal to various conditions at one's treatment works and to record the results obtained, but such data may be most useful to the sanitary engineering profession generally.

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## OHIO STATE DEPARTMENT OF HEALTH
## PUBLIC HEALTH COUNCIL

*July 15, 1937*

To All Health Commissioners:

*Regulations Governing Operating Personnel of Water and Sewage Treatment Works*

*Regulation 236.*—All cities, villages, counties, public institutions and corporations now operating or which may hereafter operate any water or sewage treatment works shall be required to place such treatment works under the supervision of a trained individual whose ability to perform the duties required shall have been certified to by the State Director of Health, provided that nothing in these regulations shall be construed as preventing any such city, village, county, public institution or corporation from continuing in office any qualified person now so employed. The application of these regulations shall be extended to the operating personnel whose duties may include responsible charge of operation of water or sewage treatment works for any period of time.

*Regulation 237.*—The Director of Health shall set up rules pertaining to the examination, classification and certification of persons in charge of water and sewage treatment works now in operation or hereafter placed in operation.

*Regulation 238.*—The Director of Health shall prescribe the classification required of the individuals to be in charge of each such water and sewage treatment works including both the individual charged with the supervision of said works and the operating personnel whose duties may include responsible charge of operation of said works for

any period of time, such requirement to be subject to change at the discretion of the Director of Health.

*Regulation 239.*—After this date no city, village, county, public institution or corporation shall employ as the responsible individual in charge, or any individual whose duties may include responsible charge of operation, of a water or sewage treatment works, who has not been certified by the Director of Health as competent to hold such responsibility.

*Regulation 240.*—The Director of Health shall prescribe certain tests to be made and records of the operation of each water and sewage treatment works, such records to be filed monthly at the office of the Department of Health, State of Ohio.

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*Schedule.*—The foregoing regulations governing the operating personnel of water and sewage treatment works (numbers 236 to 240, inclusive) shall take effect and be in force from and after August 1, 1937.

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## NORTHWESTERN OHIO SEWAGE CONFERENCE

### EXCERPTS FROM REPORT OF JUNE MEETING

DELPHOS, OHIO, JUNE 22, 1937

The Delphos plant, equipment, buildings, floors and grounds were completely refurnished, repainted, slicked up and trimmed for the occasion of the meeting as was the Bowling Green plant for the May meeting. It is feared that, to date, the operators are setting too fast a pace for all members of the Conference to follow and the top efficiency standard might well be awarded to one of the last two host plants. This in a very material way proves the value of the Conference with respect to plant maintenance. Care must be exercised to avoid making the Conference a nuisance in the eyes of municipal officials.

Sewage treatment experts agree with health departments that representative, weighted samples of sewage flows are most difficult to procure and that unless such samples are available, the laboratory work is worse than useless, because it gives the operator, either a false sense of security or a feeling akin to a panic. The motto of one sewage treatment plant in the Conference is "It doesn't pay to kid yourself," which is varied sometimes with "We do good work."

The Delphos plant reported sludge sales for use in agricultural grain drills, being ground in a corn-sheller and screened by hand through 8-mesh hardware cloth, at a price of $4 per ton. One customer was reported to have purchased $135 worth for this purpose. This is the first instance known where ground sewage sludge has been used in a grain drill, similarly to commercial fertilizer and perhaps will open a new avenue of sales to sewage plants, that are equipped for grinding and screening. The Delphos sludge house is lighted and summer sludge-removal is done at night to avoid the excessive heat of working under glass in a blazing sun.

The members were gratified at the number of visitors present and the manner in which Delphos conducted the meeting. Interest in the Conference is increasing and each visitor to each plant learns something to his plant's advantage, the host operator also finds solution to some of his problems when presented to an operators' "clinic."

## JULY MEETING

COLUMBUS GROVE, JULY 22, 1937

An omission was made in the report of the Delphos plant meeting in June with respect to the fact that they have had unqualified success with the use of stone sand on sludge drying beds instead of pit or lake sand. There is a considerable saving in cost, in favor of stone sand, and there would be unquestionably considerable saving in transportation costs in some localities.

Hugh stock piles of stone-sand in evidence at all quarries indicate that the accumulation of sand in the process of sizing ballast and aggregate has been an item of expense, if not a nuisance to the stone companies and suggests that municipalities and engineers might well investigate the possibilities demonstrated by the resourcefulness of the Delphos management.

The diversified devices installed for the treatment of the Columbus Grove sewage were inspected and examined by the members with profound interest. It is the first plant visited to include a float-controlled, mechanically-operated, interceptor gate; a ferrous chloride "tower" with facilities for dosing either chlorine or ferrous-chloride as pre-, split- or post-sterilization according to the plan developed by Scott-Darcy using crushed tin cans and chlorinating from the bottom to provide iron salts for both modified chemical precipitation and odor control through sterilization; the first rotary distributors operating on hydrostatic head; the first city magnetite filter as secondary or final tank; the first city water pressure-booster, required because of small mains from the city reducing effective pressure and the pressure needed to wash filter media in the rotary distributors. Eighty pounds water pressure is provided by the booster pump; and the first plant with so great a degree of refinement of sewage of such concentration and strength to be staffed with but one man.

Mr. Blosser, Columbus Grove operator, who deserves much appreciation from his fellow-citizens for his man-sized job, introduced Mayor McCulloch, his boss, to the Conference. Mayor McCulloch stated in no uncertain terms that at the inception of the sewage plant idea, he was not sold on it and in fact was very much against the plan, but as the construction started and was carried through to completion he began to be more in sympathy with the proposition until now he gave it his whole-hearted approval and was willing to cooperate to the fullest extent in the operation, even to the point of promising to have Mr. Blosser's chair repainted, "especially where the seat is worn off."

Mr. Floyd G. Brown, of Marion, Ohio, designing engineer and technical supervisor of the Columbus Grove Plant, gave a detailed description of the plant and thoughtfully explained the various reasons for the selections of the devices as installed.

The plant treats the wastes of a population equivalent of 5,000 people; designed for 2,000 population equivalent in milk waste in addition to 3,000 citizens. The normal flow design is for 0.5 M.G.D. with facilities for handling 1 M.G.D. The pollution of Plum Creek has been a source of complaints for 16 years prior to building the plant. Judgments were obtained against the city due to the combined effect of milk and domestic wastes. The plant was constructed by Bever & Morris of Cleveland at a cost of about $83,000, under P.W.A. 45 per cent federal grant.

Sewage enters the plant through the float controlled, electrically-operated gate and conventional manually-raked bar screen, thence to a wet well where float controlled pumps lift it to a primary tank, with central feed and continuous peripheral weir, known as "Si-feed." Primary effluent is screened by perforated galvanized buckets placed in the out-fall to protect the rotary distributors from coarse particles carrying over. Two rotary distributors filter the primary effluent through 7½ feet of sized limestone containing 6 inches of granite on top to withstand weathering conditions. Amere filter block conducts the filter effluent to the comparatively small magnetite filter for final settling of the biologically reduced sewage. This unit attracted more attention than any other feature of the plant. One can actually see the solids being removed from the iron oxide and being pumped back into the body of the tank.

Primary sludge is pumped direct to a Dorr digester and the final or secondary sludge is allowed to return continuously by gravity in a small pipe line to a point just back of the bar screens. There is provided a larger line from the secondary tank through which sludge may be returned by gravity or pumped to the digester if desired.

The Columbus Grove Plant is extremely flexible in operation and it is possible to bypass any unit or put the sewage through any desired unit in whatever sequence necessary.

A small laboratory is provided for routine tests and a feature of the pump house is the housing of all electrical apparatus and the switch-board in a room which may be tightly closed against any corrosive fumes or gases that might cause deterioration of the metals.

The operation will be financed by a sewer rental of $6 per connection per year, although this is not yet being collected, nor are the contractors released from the job, the final estimate is yet to be paid. Consequently the analytical data, due to shortness of operation, do not indicate the real value of the work the plant is doing, but so far it has the appearance of being very efficient in all respects.

In answer to question, Mr. Brown stated that the milk waste is taken whenever it is dumped at the milk plant in order to treat it in as fresh condition as possible, rather than to store it and feed it into the sewage at a nominal rate and thereby risk soured milk, which would increase the operating difficulties. Raw sewage B.O.D. was reported to be as high as 1,000 p.p.m. and removal about 80 per cent.

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## ORIGIN, ORGANIZATION AND VALUE OF THE LONG ISLAND SECTION OF THE NEW YORK STATE SEWAGE WORKS ASSOCIATION *

By Lawrence L. Luther

*Secretary, Long Island Section, N. Y. S. S. W. A.*

Long Island is 119 miles long and 28 miles at its widest point. Its population by counties is as follows:

| | |
|---|---|
| Suffolk | 185,000 |
| Nassau | 350,000 |
| Kings | 3,000,000 |
| Queens | 1,750,000 |

Long Island is both metropolitan and rural. Its rapid growth has naturally created problems that have taxed the ingenuity of sanitary engineers during the past few years. However, these problems are being met and sewage treatment and disposal plants are being built as rapidly as funds can be appropriated by public officials, who realize that this all important health problem is one of the most serious in the development of what we Long Islanders term the "Garden Spot of the World."

There are at present 36 sewage treatment plants on the Island. Their diversity of treatment and operation is as varied as the weather. However, they are operated and maintained by a personnel of well trained superintendents and operators.

* Presented at the Spring Meeting of the New York State Sewage Works Association, Utica, N. Y., June 3, 4 and 5, 1937.

## Origin

During the early part of 1934 at one of the meetings of the N. Y. State Sewage Works Association, it was noted by some few of us that Long Island communities were not sending very many of its plant operators and superintendents to the State meetings, and furthermore, a very few of these men were members of the N. Y. S. S. W. A. It was then and there decided by a few of us that this condition was not a healthy one and that something must be done about it. It was felt that our operators needed the assistance of the State organization and furthermore that these men should be known to each other. Wellington Donaldson, whom you all know, made it his business to personally contact every plant operator and superintendent on Long Island during the months of June and July in 1934. During this survey he ascertained that the men engaged in this field were not only vitally interested in their work, but were anxious to fraternize with each other and gain additional knowledge in the science of sewage disposal. As one of our plant operators in Suffolk County expressed it "I believe that I can become a better operator by knowing how the other fellow solved his problems which must be the same as mine."

On August 9th, 1934, the first meeting of the Long Island Section was held at Freeport. There were present at this meeting 24 men. A very frank discussion took place as to the worthwhileness of creating a Long Island Section of the N. Y. S. S. W. A. We found that many of the operators were unable to attend State meetings for financial reasons. Furthermore, the various Boards of Sewer Commissioners and Boards of Trustees were not familiar with what the N. Y. S. S. W. A. was and what it meant to the community. It was decided then that one of the most important things to do was to educate the governing bodies of the cities and municipalities of Long Island to the point where they would realize the necessity of sending their operators to the State meetings and to further demonstrate to them that these meetings were educational and not junkets. Two very important things were decided at this first meeting: first—a person to be eligible for membership in the Long Island Section of the N. Y. S. S. W. A. must be a resident of Long Island actively engaged in the operation and management of a sewage treatment plant and a member of the parent body, and second—that a Board of Directors comprising representatives from all four counties, together with a secretary-treasurer, must be appointed and that the meetings would be held quarterly in various sections of the Island.

This first meeting was most encouraging. The enthusiasm with which those present responded left no doubt in the minds of all that the Long Island Section would be successful. One of the things that worried us and I think caused some doubt in the minds of the officials of the N. Y. S. S. W. A. was the possibility that the Long Island Section might draw members from the parent body and affect the attendance at the State meetings. In order to overcome this it was definitely decided that a person to be eligible for membership in the Section must

first become a member of the parent body. These fears were entirely unfounded as the figures today demonstrate conclusively that 25 per cent of the membership of the N. Y. S. S. W. A. is composed of Long Island men; in fact the membership of the Section has now reached a total of 112. All of this work has been made possible through the dogged perseverance and determination of men like Wellington Donaldson, Rodney Cook and others too numerous to mention.

The attendance of these sectional meetings has increased from 24 to a total of 86 during the 2½ years that we have been organized. I think it is most fitting and appropriate at this time to publicly thank the New York State Health Department and its entire staff for the splendid cooperation we have received from them.

As stated previously, our meetings are held quarterly in various sections of the counties. The usual procedure is to meet at a central point where registration in the early afternoon takes place. From there a tour of inspection is made to nearby sewage treatment plants. Dinner is served at 6:00 P.M. A short business session follows, after which a technical session takes place. These technical sessions last for about three hours—such topics are discussed as:

Where is the Best Position for Single Chlorine Application?
Auxiliary Chlorination and Odor Control
Removal and Disposal of Grease and Scum
The Operation of Imhoff Tanks
Experience of Sludge Digestion
Gas Utilization
The Protection of Coastal Waters
Progress of Chemical Precipitation
Maintaining Proper Digestion with Lime
Laboratory Demonstrations
Etc., Etc., Etc.

A few month ago a Laboratory Control Committee was appointed composed of Rodney Cook, Cornelius Kelly and Willard Sweeney. It was decided by these men that demonstrations on laboratory control work should be made a part of the program of at least two of the quarterly meetings. Therefore, at our last meeting held at Huntington this was done. Through the assistance of this Committee a part of the program was allotted to not only demonstrating, but actually making various laboratory determinations. This part of the program was enthusiastically received and we feel will be quite helpful.

## Finances

No dues or assessments are levied against members of the Long Island Section. We are a self-supporting and self-sustaining group. A dinner charge of $1.50 is made against each member attending the various meetings. Our meals usually cost between $1.00 and $1.25. This leaves a margin to cover the cost of mailing and stationery. In

addition to this the N. Y. S. S. W. A. makes an allotment of 50 cents per year for each member that attends at least one meeting per year. Last year this amounted to $38. This sum together with balances left from quarterly meetings has created the magnificent surplus of $17.42.

### Value of Organization

It is our opinion that Sections such as ours will go a long way towards making better operators and will bring home forcibly to not only the men but to the officials of the communities from which these men come, the importance of their work and the reason for gaining additional knowledge. It has been found that by holding our meetings in various sections of the Island that we secure an attendance of the officials of that community, thus bringing forcibly to their attention just what we are undertaking and the sincerity of purpose behind these meetings. Any fear that these Sections will prove detrimental to the attendance of the State meetings insofar as the Long Island Section is concerned is unfounded; on the other hand, we have found that these sectional gatherings have created a thirst for additional knowledge. Not only has the Long Island Section grown and prospered but the parent body has increased its membership considerably by the desire on the part of the men to satisfy this desire. I believe within the next year we will see at least six such sections in the State.

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## THE IOWA SEWAGE TREATMENT CONFERENCE

Iowa State College, Ames, Nov. 12-14, 1936

### Foreword

Practically every incorporated village, town and city in Iowa is confronted with the troublesome and perpetual problem of satisfactorily disposing of the community's used water supply. In most cases the problem is a complex technical one involving public health and possibly the creation of nuisance conditions. The operation of municipal sanitary facilities costing many thousands of dollars is involved, as well as protection of the city against suits for damage.

The State Sewage Treatment Conference held at the Iowa State College each year, gives assistance and information on these matters to city officials, engineers, superintendents and operators of sewage works, and others responsible for supervision and operation of municipal and industrial sanitary facilities. The Engineering Extension Service of the Iowa State College and the Public Health Engineering Division of the State Department of Health cooperate in organizing and conducting the Conference, utilizing the best leadership available in this field in the midwest.

The program is planned to give those attending a general understanding of the complex problems involved, together with suggestions

on the operation of individual sewage works. The Conference offers city officials as well as operators the opportunity to compare notes and get help on specific problems.

LINDON J. MURPHY,
*Municipal Engineer*

## EXCERPTS FROM OPERATORS' DISCUSSIONS

### PLANNING THE OPERATION OF A MUNICIPAL SEWAGE WORKS

BY E. E. TRUCKENMILLER, *Supt. of Utilities, Sibley, Iowa*

Sibley is a town of about 2,000 population and used to have an old septic tank until about six years ago when we decided to build a new disposal plant.

We worked out what I feel is a pretty good system of taking care of our plant. The operator goes down every morning and pumps the sludge from the clarifier to the digestor and washes down the clarifier screen, takes off the scum if any, and looks at the nozzles. This takes about an hour. He goes back about five in the afternoon to see that everything is in shape. In summer it takes a little more time than in winter. He does not always pump at night during the winter months—merely goes down to see that everything is all right, and by the way we have our weather station down there and at 6 o'clock he takes the temperature reading and the barometer indication of rain and snow. We try to keep track of our meter readings each day.

On Saturday afternoon the operator "cleans house." He gets into the pump pit and dosing chamber and washes down the walls and scrubs them, flushes them out and gets all the scum off the inside of the tanks. He also makes all of the tests that we make then. We take samples and get settleable solids. We make our relative stability test, also pH test. It takes about four hours Saturday afternoon to do this work. We balance our readings each Saturday afternoon. That gives us a check to compare one week with another. I think we are running our plant quite economically for the size of it.

*Question:* What does it cost to operate?

Answer: With power and labor it runs about $50 a month. Of course we make our own power at the municipal light plant and we charge the sewer plant for it.

*Question:* What other duties does your operator perform when he is not at the plant?

Answer: We keep this man at the light plant, unloading coal and various work about the plant. He works about 8 hours at the light plant and about 1½ hours per day at the sewage plant.

Last year our Farmers' Creamery was the largest cooperative creamery in the state of Iowa. We found that it used one quart out of every gallon of water pumped. We have a very large waste from the creamery and once in a while it causes quite a little trouble.

*Question:* About how many gallons of waste water goes out in a day?

Answer: From 80,000 to 90,000 a day. That is practically all city water—very little ground water.

*Question:* Do you use chemicals in treating your sewage?

(Truckenmiller): We do not use chemicals. If sewage is acid, we add lime but we haven't had to add any lime for 18 months.

*Question:* What percentage of total water pumped goes into the sewer?

Answer: About 80 per cent.

*Question:* Talking about having things on schedule, I would like to ask if this two hours a day is regular or just between times?

Answer: Regular. The operator goes right from his home in the morning down to the sewage plant. In the evening it varies from a half hour to an hour. That is his work. The sewage plant comes first. It usually takes less than a half hour. With this plan, he can get one unit done. If there are some things that do not necessarily have

to be done that day they can be left over but he checks the plant and sees that it is working properly. It depends on what work is scheduled for him when he gets back to the light plant. Ordinarily it requires about two hours a day.

*Question:* As population increases, does operating cost increase in the same proportion?

Answer: Not always. As population increases, the labor cost may for a time remain the same. In general the operating cost per capita is likely to be less as we increase in population.

## HAZARDS IN CONJUNCTION WITH SEWAGE WORKS

By A. H. Wieters

*Director, Public Health Engr. Div., State Dept. of Health, Des Moines, Iowa*

There is a health hazard if the operator is careless in transferring sewage and in his work in general. Extreme care should be taken in this work.

I feel rather keenly that we can't be too careful in connection with the gas hazard. Sewage gas is toxic, explosive and very dangerous. We have had two fatal gas accidents in Iowa, both in deep sewer manholes. Sewer gas is particularly dangerous in Iowa as we have so much sulphur in the water, and yet the average workman is apt not to take it too seriously. Familiarity breeds contempt, you know. If there is sulphur present, the smell is strong and you have a warning which should be heeded. However, there are other gases that do not give off an offensive odor. They deaden the sense of smell.

Carbon monoxide is second on the list of deadly gases. One good breath of carbon monoxide will kill. Great care should be taken in working with tanks, manholes and pumps. We have required that some experimental plants make special provision for ventilation and removal of gases. I would certainly suggest that no man go into a tank or manhole without a safety belt.

I would like to say a few words more in regard to the explosion hazard. At a sewage treatment plant in Rhode Island it became necessary to make some repairs on the sludge machinery. The tank was drained and the manhole left open. The superintendent and two workmen at the plant had been warned of the gas and explosion hazards. One of the men started down into the tank and about the time he reached the bottom of the manhole there was an explosion that blew the concrete top off the tank just like a matchbox.

I have a very wholesome respect for sewage gas. The possibility of having explosions are many and particularly when the men are not accustomed to working with gas. In certain proportions oxygen (air) mixed with gas forms a tremendously explosive mixture.

### Discussion of Operating Problems

*Problem* (Baker, *Newton*): We have had trouble with foaming as well as with acid condition. I did not know it was possible to have foaming without acid condition. We should have had perhaps five feet more of sludge in the bottom of the Imhoff tank. The foaming was so bad that it was coming over the top. The foam just stayed there and would not settle down. The only thing that did any good was to just break it up.

Hatfield: Of course, you have foaming with acid condition, due to overloading. It is just a matter of having a tremendous gas volume at the particular time when you have been caught with an extra amount of scum on top of the gas tank. You can tell when the foaming is coming by the bubbles forming. The only thing that you can do is to punch it gently, stir it, but not violently.

*Question:* In conditioning plants for winter, what do you do with the Imhoff tanks? How is the sludge handled?

Answer: An ideal to aim at is to have as much sludge as you possibly can in your tank. Draw out small amounts often and not all at once, because that upsets the equilibrium of your tank. You may need to have considerable available sludge storage space, and also a lagoon for emergency storage. We found it necessary also to double the capacity of our sludge drying beds in order to secure most efficient winter operation.

Baker, *Newton:* According to what Dr. Hatfield has said, I am quite sure that we did not carry enough sludge. We have three plants that have ample capacity; one that doesn't. We have to draw out the total amount of sludge about every six weeks. We can't build up seed.

Galligan, *Ames:* At the Boone, Iowa, plant one spring several years ago, the operator had a difficult problem that was traceable to a change in temperature. The solids that had been deposited during the winter accumulated in relatively large quantities in the flatter portions of the sewers and sloughed off in large chunks and in such large quantities that the flowing through chambers of the Imhoff tanks were virtually filled with this undesirable and unmanageable material. It is needless to say that this material had to be bailed from the tanks.

Hatfield, *Decatur, Ill.:* In reducing foaming on Imhoff tanks I have had the best results by sprinkling with a gentle spray. If you get a good rain for about an hour on an open Imhoff tank the foaming will disappear. So I use a gentle spray of water resembling rain. One method is to run a 2-inch pipe along the gas vent and about every four feet put in a valve. Hang pieces of board to make a spray. Leave it in operation part of the time not 24 hours a day.

Another plant made spray out of a piece of hose on a pipe. Get gentle drops of water like rain falling over a large area. If you use hose on a pipe you are likely to have too strong a spray and it washes the foam aside and does not treat it over all of the surface and you do not get the desired results—just makes it worse. Sewage tank liquor can be used for recirculation if water is too expensive. You can break up the sludge on the surface every day with a hoe or a stumper.

*Question:* Regarding the trickling filter, do the stones break up from freezing in winter? Are there difficulties in either summer or winter operation?

E. E. Truckenmiller, *Sibley:* We have no change in our trickling filter in winter as it is all housed. When the temperature gets down below 30° F., we close the windows and doors at night, but we experience no difficulty during the colder weather. Relative to the freezing of nozzles when dosing ceases, some operators have reported that it was necessary to take the nozzle off during the extremely cold weather of last winter.

Hatfield: About freezing of sprinkler nozzles during extremely cold weather, I believe some of the men have mentioned that they had to take off the nozzle during the colder weather. Another method is to crack the valve at the dosing tank at night when it is apt to freeze up. Have a two foot drop to get away from that very rapid freezing or the ends of the distribution lines may be left slightly open. It is important to get an opening any place where it may be possible to drain the distribution system after the spraying is over.

C. H. Currie, *Webster City:* A word as to stone freezing and breaking. Yes, some stone does break when it freezes in the trickling filter. At Mason City they had to repair the old building and plant where limestone had been used. I have seen cases where the breaking of stone is serious. A great many plants report breaking up of rock, and I do not believe that we can get material that will not break down to some extent. Limestone breaks up and is too soft for permanent use. The best rock to use in filters is quartzite. We are continually studying the problem of what should be the tests to determine the real wearing qualities of rock for filter use. Acceleration tests seem too severe. The rock at Jefferson is a good illustration. We put those under the generally accepted tests and they broke down immediately but had stood the test of actual use for 20 years. It may not be a fair test of what happens out in the open where it freezes and thaws. Engineers all over the United States are still a little bit up in the air to

know what rock will stand up in sewage filters. However, the best would break up some in 15 years and additions would have to be made.

*Odors.*—E. G. Fiala, *State Dept. of Health, Des Moines:* A large number of plants are built with a capacity sufficient to provide for a greatly increased population in the future. They often have a tank much too large. If the raw sewage is allowed to stand too long there is a bad odor, particularly in hot weather. The first thing that comes to mind is to cut down the detention period. Use only one tank if you have two or three. Put the sewage on the filters in just as fresh a condition as you can, to get away from odors.

Chlorine can be used on the raw sewage. In some plants chlorine is used only when the wind is in the direction to bring the odors to the city. In some seasons the wind is always the other way.

*Operation Tests for Small Plants.*—F. W. Mohlman, *Chicago:* Tests to determine the operating efficiency of sewage works vary with the size and type of plant and the character of sewage and wastes. For small sewage treatment plants the tests can usually be few and simple. They may have to do largely with the effectiveness of settlement and digestion. It is important to have a simple but accurate record to show the State Board of Health and others who may be interested in just what your plant is doing. The record of operation will usually be more significant than the chemical tests.

Operating records should include:

1. Average flow (in million gallons per day).
2. Hours of operation.
3. Shutdowns and by-passing.
4. Storm flows.
5. Gas production—foaming.
6. Sludge drawn—volume—character.
7. Stream conditions—sludge banks.

While many small sewage works may not be equipped with flow meters, no plant is so small but that a sharp-edged weir can be rigged up to measure the flow. From charts it is then a simple matter to figure out how much sewage the plant is treating. It is also possible to get the hourly fluctuations.

With the small sewage works only two simple chemical tests may be necessary. They are:

1. Settleable solids.
2. pH of sludge.

Where the small sewage works includes trickling filters or activated sludge the following records are important:

### A. Operating Records

*Filters*
- Hours operated.
- Unloading.
- Surface condition.
- Flies.
- Condition of secondary tank.
- Stream conditions.

*Activated Sludge*
- Hours operated.
- Sludge in final tanks.
- Settling tests, aeration tanks.
- Aeration period and per cent returned sludge.
- Air, cu. ft. per gallon.
- Stream conditions.

### B. Chemical Tests

*Filters*
- Settleable solids.
- Rel. stability.

*Activated Sludge*
- Settleable solids.

For small plants, a daily log of flow, by-passing, gas production, sludge removal and continuity of operation of filters or activated sludge is better than any chemical tests. The condition of the river should be noted, as should also the presence of sludge banks, growth of algae, odors, etc.

The keeping of records is an indication of your interest in the plant. This interest will keep on growing as you work on these records and understand them better. They will help you to understand the working of your plant and to operate it more intelligently and efficiently.

# Editorial

## NEW TOOLS FOR PLANT CONTROL

This issue contains a number of papers that should be studied carefully by the plant operator, for they contain information that should prove to be very helpful to him in extending his understanding of the processes under his control. New tools, both physical and chemical, are being offered to the operator as aids in plant control and operation. Use of these tools, gadgets or tests is frequently brought out in operators' round tables at association meetings. Sometimes reports of operators' sessions may seem dull or innocuous, but frequently one finds a gem of a suggestion in a dross of words, like the pearl in the oyster or the isotope in the atom. But what may be the prize for one may be of no interest for another, therefore it is necessary to print a rather voluminous amount of discussion on operating problems in the hope that the topics may interest various types of readers.

Prepared papers on phases of plant control are more specific and usually they discuss and elucidate questions of interest to all plant operators or designers. For example, the paper by Mr. McDill in this issue, on per capita B.O.D. factors, contains data that are remarkably consistent and conclusive. With compilation and reporting of more such data we may be able to determine more precisely the effect of industrial wastes on plant loadings and reasons for differences in behavior of various sewages. It may not be too much to hope that, in time, B.O.D. per capita factors may be used for evaluation of sewage treatment rates, with legal recognition. More data like those summarized by Mr. McDill will help to establish the authority of such factors.

An interesting use of the B.O.D. data in control of activated sludge plant operation is given by Mr. Berg of San Antonio. Computations of the cubic feet of air per pound of B.O.D. in the primary effluent seem to be inversely correlated with the sludge index—in other words, as the air goes down, the sludge goes up. Undoubtedly similar relations have been noted by other operators. However, for plant control, the 5-day B.O.D. offers rather a belated test, and a more immediate result would seem desirable.

Other tools are presented in other papers in this issue. Chujo shows the advantage of using the carbon dioxide in digestor gas for the purpose of reducing the pH of too alkaline sewage. In this work he seems to be following the lead of Singleton at Atlanta several years ago. The differences shown by Chujo between treated and untreated sewages are surprising.

The use of chemical precipitation in sewage treatment has brought out many new coagulants or mixtures of chemicals. Yaffe at El Paso

gives some surprisingly satisfactory results with quite small amounts of ferric chloride, and he also offers valuable advice on how to prepare home-made iron salts. Additional chemical tools that are being proposed for sewage include the use of alum, which is understood to have been quite successful in tests at Ridgewood, N. J., and at Colorado Springs, although not so successful elsewhere. Alum seems to vary considerably in effectiveness with different sewages. As yet, very little if any experimentation on sewage has been reported on the use of Baylis' alum plus silica, which seems to give such striking results in water coagulation.

Experimental work at Iowa City on the use of bentonite for clarification of sewage shows that it has considerable merit if used in large amounts. However, the amount needed to obtain good results is apparently very large (more than 500 pounds per million gallons) and therefore this process may prove to be prohibitively costly. Another experimental use of unusual, and in this case costly, materials is the Henry process, in which starch is used along with a coagulant for sewage clarification. This process has been investigated in England and France, but very little has been published concerning the tests of the process. The use of charred sludge has been reported at St. Charles, Illinois, but no controlled data are available to show what it does. Mr. Haywood, in this issue, cites the use of activated carbon at several plants. Undoubtedly other materials than those mentioned above are being tried out at various plants, and from these tests may evolve new and improved tools for sewage clarification.

Digestion difficulties seem to be perennial. Mr. Haywood has had some success in using activated carbon for reducing foaming. Just why he mentions sludge temperatures, before and after adding carbon, does not seem clear, for he does not claim that the carbon was responsible for the increase. Dr. Rudolfs cites several toxic wastes which seem to have a powerfully repressive effect on sludge digestion. The detrimental effect of copper has been noted at New Haven, Muskegon Heights and elsewhere, and undoubtedly other cases of stubborn resistance to digestion may be ascribed to the presence of one or another of the wastes studied by Dr. Rudolfs.

This discussion by no means exhausts the list of practical aids to the plant operator that are discussed in this issue. The alert operator may pick up just the suggestion he has been looking for, where least expected.

F. W. M.

# Reviews and Abstracts

H. W. Streeter

## EXPERIENCES WITH REAERATION OF ACTIVATED SLUDGE AT THE STAHNSDORF PLANT, BERLIN

By Dr. Georg Böttcher

*Gesundh.-Ing.*, 59, 67 (1936)

In the ordinary activated sludge plant, the detention period in the aeration tanks of approximately six hours is made up of about one hour of purification of the sewage and about five hours of reaeration or regeneration of the sludge. When the sludge is reaerated, the sewage and sludge are aerated for a short period, the sludge is removed from the purified sewage and then the sludge is aerated alone for a period of ten to twenty hours.

To provide for unforeseen difficulties in the treatment of a very septic sewage at Stahnsdorf, provision was made to aerate the sewage and sludge for six to eight hours and then after the separation of the sludge from the purified sewage to again aerate the sludge for six to eight hours. During the first two years of operation with reaeration of the sludge it was observed that the initial period of sludge formation was unusually long because the reaeration tank had to be filled. Sludge bulking with the formation of a filamentous fungus also developed.

It was impossible to operate one group of aeration tanks with reaeration and one without because of an insufficient flow of sewage but the tests were made with each over a sufficiently long period to obtain a clear picture.

In the primary settling tanks, 90 to 95 per cent of the settleable solids was removed. The total nitrogen content of the raw sewage was about 30 p.p.m. and the B.O.D. about 300 p.p.m. In the settled sewage the B.O.D. was reduced to about 200 p.p.m.

As a preliminary experiment, the dissolved oxygen was determined in filtered samples of sludge taken at various places in its course through the plant and, although the results were only relative because of errors during filtration, the dissolved oxygen was 3.4 p.p.m. in the aeration tanks, 2.2 p.p.m. in the secondary settling tanks, 2.8 p.p.m. in the inlet to the reaeration tank and 2.3 p.p.m. in the outlet. Further tests showed that, on the average, the dissolved oxygen in the inlet to the reaeration tank was 2.3 p.p.m. and in the outlet 2.16. In 1933, during nine weeks' operation without reaeration of sludge, the average nitrate content in the effluent was 27.7 p.p.m. with a sewage flow of 4.75 m.g.d. and with an addition of 0.66 cu. ft. per gal. of air. For comparison, during seven weeks' operation in the same months of 1932 with reaeration of the sludge, the average nitrate content was 20.1 p.p.m. with a sewage flow of 3.3 m.g.d. and .82 cu. ft. of air per gal. of sewage.

Reactivation in the primary aeration tank without reaeration of the sludge has been very satisfactory. A 50 per cent increase over the usual rate of air addition and the elimination of the reaeration tank resulted in high nitrates in the effluent and the elimination of sludge bulking and slow initial period of sludge formation.

In the activated sludge process, the organisms do not need a rest period after hard work, as higher animals do, but eat what they find and continue propagating.

Too much aeration is as injurious as too little. At the Stahnsdorf plant the lower limit for satisfactory operation is 0.52 cu. ft. of air per gal. of sewage during a 6 to 8 hour aeration period. With 0.45 cu. ft. a decrease in nitrates occurred and with 0.8–0.9 cu. ft. the purification, as measured by the nitrates and B.O.D., was very good but the sludge bulked.

In primary aeration tanks where sewage and sludge are aerated together over-aeration is injurious, but a strong aeration of the concentrated sludge alone may be even more disadvantageous.

The biological process of sewage purification by activated sludge may be explained as follows: With customary aeration $\alpha$-$\beta$ meso-saprobic organisms are required for maintaining the biological balance. With under-aeration $\beta$ meso to poly-saprobes cause sludge bulking because of the development of filamentous fungi. With over-aeration, oligo-saprobes cause another type of sludge bulking by the development of protozoa.

G. P. EDWARDS

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## OPERATING RESULTS AT THE NÜRNBERG–NORD SEWAGE TREATMENT PLANT

BY WERNER MÜLLER

*Gesundh.-Ing.*, 59, 152 (1936)

The Nürnberg-Nord sewage treatment plant, which has a contributing population of 250,000 and receives 13.2 million gallons of sewage daily, has been in operation for five years. The hand-cleaned racks which have openings 2 in. wide are provided with rag catchers having openings about 3 in. wide. Of the screenings, only the large substances, such as wood and rags, are composted and all digestible substances are returned to the sewage below the racks. In this way the solids which cause nuisance from odor and which are difficult to handle are kept to as small a volume as possible. The screenings amount to about 3,530 cu. ft. per year or nearly 10 cu. ft. per day.

The sand retained in the two-channel grit chamber (each channel 82 ft. long) is fairly clean. The small amount of sludge which settles when the velocity is low during the night is stirred up with a wide wooden rake and washed out when the racks are first cleaned in the morning. The grit is removed by hand about every four weeks, each removal requiring 16 man-days of labor. About 17,650 cu. ft. of grit are removed per year or an average of about 50 cu. ft. per day.

It is difficult to distribute the sewage equally to four settling tanks. In dividing the sewage the suspended solids tend to be diverted from the main direction of flow so that the first tank usually contains a heavier load of solids than the second. At the Nürnberg-Nord plant the sewage is divided into two equal parts and each part again divided into two. The sewage is deflected into the first tank by a curved, sloping metal sheet set on edge, the smallest side of which points against the direction of flow. The sharp upper edge, which slopes 1 : 2, is covered with a pipe to prevent the solids from hanging to it.

Although the detention period of the sedimentation tanks is only about 1.25 hours the average removal of settleable solids during the six warm months was 94.8 per cent. Since the sludge removal with the Leipzig type of equipment is nearly continuous no sludge storage space was provided. It is important in tanks of this kind to have the sludge withdrawal pipe placed under the concrete so that sludge can easily slip down into the sludge hopper. The skimmings from the settling tanks are added to the digestion tanks.

During the operating year, 1934–5, a total of 3,530,000 cu. ft. of fresh sludge was obtained, an average of 9,637 cu. ft. per day or .039 per capita per day. From the digestion tanks 575,390 cu. ft. of digested sludge were withdrawn, which, together with 130,610 cu. ft. of sludge from the supernatant liquor, made a total of 706,000 cu. ft. of digested sludge, an average of 1,940 cu. ft. per day. A total of 240,000 cu. ft. of dried sludge is removed from the sludge beds annually, an average of 671 cu. ft. per day.

The easterly group of four digestion tanks, having a total capacity of 105,900 cu. ft. was constantly heated to 77° F. whereas the westerly group of four tanks, which had the same capacity, was not heated. The tanks are connected in pairs by three openings in the common wall. Up to June 15, 1935, the heated tanks received two-thirds of the

raw sludge, the unheated ones, one-third. The supernatant liquor was drawn off to a tank and, after sedimentation, pumped to the unheated digestion tanks. The digested sludge from the heated tanks was pumped to the unheated ones. The average temperature of the second stage was 68° F.

In 1934–5, 52,838,000 cu. ft. of gas were obtained. Of this amount, 35,416,000 cu. ft. or about two-thirds came from the first stage. The average total gas produced was 144,730 cu. ft. per day or 0.58 cu. ft. per capita per day. Addition of the sludge to the digestion tanks by distributing it over the entire surface of the tanks prevented scum formation, eliminated dead spots in the tank and increased gas formation about 13 per cent over the former method of adding the sludge through a pipe at one place near the surface of the liquid in the tank. The gas contained about 61 per cent methane and 32.4 per cent carbon dioxide and was entirely free from hydrogen sulphide.

Each of the four digestion tanks, which had been heated since May, 1932, contained two separate heating coils, one on the lower part of the wall and the other on the upper part of the sloping bottom. The coils are of steel pipe placed about ten inches from the bottom and side walls. The heating surface of the bottom coil is 655 sq. ft. and of the one on the sidewalls 702 sq. ft. As the heavy thick sludge at the bottom retarded the distribution of heat the lower coil was less efficient than the upper one, although neither coil became encrusted with sludge. From the upper coil 61.3 per cent of the heat was transferred to the sludge and from the lower one 38.7 per cent.

The sludge drying beds consist of layers of brick laid in dry, gravelly sand with three drainage channels through each bed. The joints of the brick are cleaned out from time to time and filled with fresh sand. The sludge dried very well.

G. P. EDWARDS

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## MODERN TRENDS IN SEWAGE DISPOSAL

BY S. G. WARDLEY AND J. A. CHRISTIAN

*The Surveyor*, 91, 889–891 (June 25, 1937)

Discussion, *The Surveyor* 92, 45–46 (July 9, 1937)

Modern biological methods of sewage treatment can fairly be said to be the result of scientific examination of natural processes of self-purification of rivers and lakes. A wider grasp of these natural processes is helping to assess at their true worth the standards of purification of which each biological process is capable. Chemical purification processes are again finding favor purely from a new conception of their true worth in relation to the capacity of natural streams for self-purification.

Self-purification operates without nuisance when the sewage is spread over a large area of ground or discharged into large quantities of water. From the former has sprung the sewage farm, and from the latter, disposal by dilution. Since the criterion for the mechanism of self-purification is oxygen, the limits of capacity of the dilution method are the power of water to retain oxygen in solution and the ability to replenish the supply. Although sea water absorbs oxygen to a lesser extent than fresh water, the concentration of salts which takes place at the surface of sea water due to evaporation results in a greater transfer or "streaming" of oxygen-saturated, denser, water downward, and this, with probably greater agitation and surface area exposed due to wave formation, results in the rate of oxygenation being approximately the same for both salt and fresh water.

While a river in some cases may have to be pure and well oxygenated, at the other end of the scale it may be sufficient that the river should carry its water to the sea without causing nuisance. Without suggesting that our rivers ought not to be improved, we feel it should be more generally recognized that rivers cannot be maintained above a certain practical standard of purity, depending upon the conditions of the district through which the river flows. The river should be left only as much work as it can do while maintaining itself at the requisite degree of purity. Sometimes only mechanical

processes such as grit removal, screening, sedimentation, etc., are needed to fit the sewage for discharge into a river, but with less favorable conditions chemical precipitation or biological treatment may be necessary. In disposal by dilution, it is essential that the sewage be free from septicity, since in addition to causing a nuisance at the plant, an unnecessary burden is being incurred. Good sewer design, frequent flushing and, if necessary, chlorination in the line of the sewer, should avoid this septicity. The larger particles of sewage are not readily penetrated by chlorine, and these may be removed by screening or disintegration. Where no screenings are removed, disintegration with chlorination is practiced if mixing in the receiving water is not sufficient to prevent the formation of sludge banks. This method has been used at seaside resorts and elsewhere, and appears to be eminently sound. The sole object of chemical treatment is to make possible, or more efficient, the after-treatment of the effluent by dilution or controlled biological means.

Screenings are among the most offensive and intractable parts of sewage, and the marked trend toward mechanization of screening has done much to allay nuisance and improve conditions of labor. In sedimentation, mechanical sludge removal in small tanks of great depth and circular plan is efficient, although advantages such as equalization of effluent strength and flocculation are better obtained in larger tanks of rectangular shape.

Except for two developments, work on percolating filters has been experimental, concerning itself with forced aeration and the application of sewage at phenomenal rates, with or without recirculation of the effluent. These two developments are bio-flocculation with percolating filters and the use of percolating filters in series. In the former, both the coagulation stage, which requires only a short time, and reactivation, can be accomplished in a comparatively small tank and the percolating filter, doing only that work for which it is best fitted, can be operated at high rates efficiently. It is proposed at Leicester to adopt this method, experimentally, with a plant designed to treat 1 m.g.d., applying the bio-flocculated effluent at twice normal rates to existing beds. It is planned eventually to convert 12 acres of contact beds to percolating filters, add the required bio-flocculation units, and treat twice the present dry weather flow on about 200 acres of land, or about 1/6 that required at present for irrigation and sludge disposal.

The other interesting development, the use of percolating filters with reversal of the order of use to eliminate ponding, requires pumping, but the rates of dosage obtained may be sufficiently high to justify the cost of pumping.

At Leicester, due to low river flows, the discharge of settled storm waters is sufficient to cause serious local deoxygenation of the receiving stream. A new plant has just been completed to chlorinate the storm water at dosages up to 5 p.p.m. for a 50 m.g.d. flow. This delays the deoxygenating effect of the storm water for about 24 hours, or until it has had sufficient time adequately to mix with the river water.

## Discussion

Mr. E. J. Silcock (Westminster) commented that the removal of solids from sewage by screening and their return after pulverizing seemed illogical. In sedimentation tanks, the use of upward flow tanks followed by horizontal flow tanks, as adopted at the new Mogden works, was similar to a combined tank which he had used for a number of years.

Mr. E. J. Goodacre (Poole) stated that he believed purification by dilution to be scientifically sound at seaside resorts. He had practiced disintegration for ten years but did not think it entirely superseded pretreatment by sedimentation or precipitation. Occasionally there appeared over the head of the outfall a slimy patch which was objectionable to the eye and probably hindered reoxygenation. This objection might be overcome by staggering outlets to give better diffusion of the sewage into the sea water. Mr. Goodacre regarded chlorination as a safeguard against accidental infection from sewage-polluted bathing waters and referred to work by Japanese chemists which indicated that certain bacteria became dormant in sea water but were revived in a suitable environment.

Lt. Col. F. C. Temple (President Inst. San. Engrs.) stated that percolating filters in series had been used in India to produce an especially good effluent for more than twenty years, but the "dodge of reversing the order of the series periodically" appeared to be new. He deprecated the tremendous waste of fertilizing substances involved in the operation of centralized plants and thought that in many instances the use of smaller plants, with discharge of the fertilizing elements on arable land, held possibilities.

Mr. Stephens (Manchester) cited the advantages of centralized treatment at places such as West Middlesex, where one large plant replaced 267 smaller ones.

R. W. KEHR

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## OPERATION OF THE DAGENHAM PRÜSS TANK

BY A. H. HOLROYD

Abstract, *The Surveyor*, 92, 39–41 (July 9, 1937)

Discussion, *The Surveyor*, 92, 145–146, 179–180 (July 30 and August 6, 1937)

Sewage enters the 94-ft. diameter tank through two inverted siphons which discharge into a concentric circular weir 11 ft. in diameter at the center of the tank. From this weir the sewage is diverted downward by a sheet steel cylindrical baffle located about 1 ft. away from the weir and extending 4 ft. 6 in. downward. A projection on the reinforced concrete supporting cone then directs the sewage toward the first distribution grid, 22 ft. in diameter, which consists of 2 in. square wooden bars, tapered ½ in. to the outside, spaced 1½ in. apart and extending almost to the tank bottom. Beyond the first grid is the inner settlement basin, of 190,000 gallons capacity and averaging 9 ft. in depth. A second grid system 70 ft. in diameter separates the inner and outer settlement basins, both of about equal capacity.

A rotary scraper, operated by a 3 h.p. motor running on a rail at the outer edge of the basin, pushes the sludge to separate hoppers, a single hopper of 2,420 cu. ft. capacity for the inner basin and three hoppers of 780 cu. ft. total capacity for the outer basin. The inner tank is skimmed. The scraper operates at two speeds, of 1 and 2 revolutions per hour, requiring about ½ hp. for a maximum peripheral velocity of 9.5 ft. per hour. With 3 hr. nominal detention, the inner basin takes 90 per cent of the sludge, but only 50 per cent at 1½ hr. detention. About 30,000 to 60,000 gal. of 93 to 95 per cent moisture content, half domestic and half waste activated sludge are obtained daily. The tank cost £6,700 and operating costs are about £140 including laboratory supervision allocation.

The sewage is fresh, largely domestic, and is screened and pumped, and receives during the day 5,000 gal. per hr. of waste activated sludge to a total of 3¼ m.g.d dry weather flow. The effect of the waste activated sludge on sedimentation of sewage solids seems negligible.

The results obtained by the tank can best be expressed in terms of four efficiency ratios: the "efficiency of sedimentation," based on suspended solids, the "efficiency of detention" which seems to be largely controlled by the "efficiency of inlets and outlets," and the "efficiency of management" or maintenance of designed conditions of operation, which seems largely dependent upon maintenance of a proper balance between the moisture content of the sludge removed and the level of the sludge layer in the tank.

In determining the efficiency of sedimentation, the use of Gooch crucibles removes some nonsettleable material and 100 per cent efficiency can never be obtained, the use of the centrifuge is more or less arbitrary and settlement in Imhoff cones was therefore adopted, the efficiency, after Clifford and Windridge, being expressed as the ratio

$$\frac{\text{Solids removed by tank}}{\text{Solids removed by quiescent settling for nominal detention period.}}$$

The American method of settling both influent and effluent a given length of time and comparing the results volumetrically proved less satisfactory since the water content of the sludge at the point of an Imhoff cone is uncertain. The practical lower limit for efficiency of sedimentation at Dagenham was two hours' nominal detention, although this limit could be relaxed for dilute storm flows. (*Abstractor's Note:* Although no data are given as to the measurements made with dyes and chlorides of the detention period of the tank, the writer seemed to think that published detention periods, based on the average flowing-through time for an added substance, of 9–48 per cent of the nominal detention period, were quite low.)

The only difficulty experienced in the operation of the tank was in the proper removal of sludge, keeping the moisture content down without allowing the sludge blanket to rise too high. In order to check the sludge level, a device was used consisting of a series of small wide mouth bottles attached to a stick and fitted with rubber stoppers and single short glass tubes closed with short pieces of rubber tubing and screw clamps. The air was partially exhausted from the bottles, the clamps tightened and the bottles lowered to the desired depth where the rubber tubing and clamp were removed by a "string and lever" mechanism. The bottle filled and could be removed without disturbance.

In conclusion Mr. Holroyd stated that he thought this particular tank, designed by Dr. Prüss, had proven remarkably efficient.

*Discussion.*—Mr. C. B. Townend (West Middlesex Main Drainage Works) considered both mechanical sludge removal and radial flow tanks to have originated in England, rather than in America as suggested by the author. He questioned whether the complicated system of baffles introduced by Dr. Prüss would improve sedimentation conditions in the tank. He criticized the 3-in. drop at the inlet to the tank as introducing unnecessary kinetic energy which would have to be dissipated to prevent undesirable undercurrents. He considered the cost, £18 per 1,000 gal. capacity, to be excessive.

Mr. F. C. Vokes (Birmingham Tame and Rea District) cited a similar sedimentation capacity provided at the Coleshill works consisting of three 44-ft. diameter tanks with rotary sludge scrapers at about the same cost as the Dagenham tank. The provision of the three tanks gave better flexibility and allowed two tanks to operate when it was necessary to shut one down for repairs or cleaning.

Mr. H. C. Whitehead (Birmingham Tame and Rhea District) considered the Prüss tank needlessly elaborate. At the Coleshill plant it had been necessary, during warm weather, to clean and hose down the sides of the tank every ten days or so.

Mr. R. Hicks (Gravesend) wished the author had given more data upon suspended solids removal in the presence of activated sludge, since such values for the density of sludge as were given indicated very good settling. With regard to the determination of suspended solids by the Gooch crucible, he (Mr. Hicks) preferred to use Mr. O'Shaughnessy's modification, in which he allows the material to stand several days in the dark to resolve the greasy and colloidal material and get a clear supernatant before filtering.

Lt. Col. F. C. Temple (India) described difficulties he had experienced with short-circuiting in a settling tank and how the difficulty had been solved by hanging a curtain of weighted bamboo poles in the tank, which gave quite uniform distribution of flow.

In replying, Mr. Holyroyd stated that he had been concerned with presenting data which would furnish a fair basis of comparison with other tanks where similar data were available. In its absence he must be excused for doubting any criticism of general efficiency as unproved. In regard to the origin of this type of tank, he realized that it was only a development and anything but a new idea. The inlet design had been changed several times and was still being studied. In regard to the cost of the tank, it was somewhat high, since 15 per cent of the total cost had been due to the necessity of special foundations. Regarding the flexibility of multiple units, the author stated that three units required more supervision and that so far as cleaning the tank was concerned, it had not yet been necessary to clean the tanks at Dagenham.

R. W. KEHR

# EXPERIMENTS ON DEWATERING HUMUS AND ACTIVATED SLUDGES

By C. Lumb and J. Hirst

Abstract, *The Surveyor*, 92, 9–11 (July 2, 1937)

Discussion, *The Surveyor* 92, 37–38, 80–81 (July 9, 16, 1937)

At Halifax, primary sludge containing a high percentage of grease from wool wastes is being economically and hygienically dealt with by cold acid filter pressing, drying and separation into grease and fertilizer. These experiments in steam cooking as an aid to dewatering are largely concerned with humus and waste activated sludge produced in the approximate ratio of 5:1 on a dry solid basis. The process consists essentially of heating the sludge with steam under pressure, decanting, usually overnight, and then pressing in twill cloth filters.

After prelimnary experiments, heating at a pressure of 150 lb. per sq. in., corresponding to a temperature of 184° C., for a period of 30 minutes, was adopted. Increased volumes of decanted liquor were obtained at higher pressures and with longer heating periods, but this was attributed to increased condensation when heating directly with steam. Increasing the pressure or prolonging the period of heating resulted in only slight improvement in the filtering qualities of the sludge. By employing countercurrent heat transfer, as much as 80 per ct. of the heat in the cooked sludge can be reclaimed.

The pressed cake produced is of good hard quality, practically free from odor, continues to drain and dries readily to about 25 per ct. moisture in one to three weeks if protected from direct rain. It is a much drier cake and of less volume than that produced by chemicals. The time of pressing required to produce a 1½ in. cake is only about three times that required to produce a ½ in. cake, whereas with chemically conditioned sludge the time required is about as the square of the cake thickness or about nine times as long.

Runs were also made using primary sludge alone, activated sludge alone, and a mixture of all sludges from the plant. The results obtained were of about the same order, activated sludge alone filtering even better than when mixed with humus.

The solution decanted and the sludge filtrate are quite high in organic matter, and there is lost in the filtrate a large proportion of the nitrogen content of the sludge. The total volume of filtrate amounted to about 0.75 per ct. of the dry weather flow, but this is higher than would normally be obtained in plant practice, since it included some condensed steam. The treatment of this waste liquor presents quite a problem; chemical precipitation does not effect over 30 per ct. purification judged by decrease in permanganate oxygen absorption; activated sludge treatment results in copious frothing; biofiltration of a 30 per ct. dilution at a rate of 45 gal. per cu. yd. per day, followed by secondary filtration at a similar rate, still requires high dilution of the effluent to meet the Royal Commission's standards; the effluent can, however, be disposed of by single filtration and return of the effluent to the incoming plant sewage.

*Discussion.* Mr. J. H. Edmondson (Sheffield), who had been in charge of the work during earlier experiments, considered the process to be the best solution yet developed for the disposal of secondary sludge at Halifax. Certain difficulties were to be expected, however, in a full scale plant; the cooked sludge had a characteristic odor; direct mixing of sewage with the waste liquors increased the plant effluent from either filters or activated sludge by 3.7 p.p.pm. B.O.D.; and preliminary filtration of this liquor would add considerable capital cost to the sludge disposal plant.

Mr. J. Hurley (Wolverhampton), who had also been in charge of the plant during some of the earlier experiments, considered that 140 lb. pressure for heating might be more desirable than 150 lb., since only 10 minutes longer filtering time were required for a ½ in. cake and the final product was somewhat better. He thought the loss of nitrogen, decreasing the salability of the sludge, a serious effect which might be decreased by using a lower pressure during cooking. The process possessed very obvious possibilities, however, which merited serious consideration.

Mr. P. G. Lloyd (Kingston-on-Thames) inquired regarding the extra amount of filtering material required per gallon of waste liquor. This was 1 cubic yard per 10 gallons of liquor.

Mr. J. H. Garner (West Riding Rivers Board) pointed out that the process originated as a Swedish "wet carbonizing" process invented by Nils Testrup. The process was used before the war as a method of making fuel briquettes from peat, but was not successful commerically. It was also tried at Huddersfield about 1911, for sewage sludge disposal, but the heating pressure, 120 lb. per sq. in., was not sufficient to render the sludge pressable, and the horizontal heating tubes used tended to choke. Grease was extracted from the dried press cake, but consisted largely of iron and calcium soaps and was not readily salable. Other difficulties encountered were the odors evolved, gas accumulation which required safety valves at various points, and the decrease in nitrogen content of the sludge below the 3 per ct. which had been guaranteed merchants. No difficulties were observed due to return of the press liquor to the incoming sewage, possibly because of the dilute sewage flow of 80 to 90 gal. per capita per day. The process was abandoned after two years and cold acid pressing adopted.

Mr. W. H. Hoyle (Exeter) pointed out that after sludge digestion, dewatering of the sludge remained quite a problem, especially in humid climates. One point which especially interested him was the reduction of solid matter, through simple heat treatment of about 20° C.

In reply to the questions raised, Mr. Lumb stated that, under plant conditions, odors would probably be handled by operating in a closed system. Although the total amount of waste liquor would be increased above the figures given in treating both primary and secondary sludge by this method, the increase would not be in direct proportion to the volume of sludge handled and there was some evidence that waste liquor from primary sludges would be easier to treat. Regarding the steam pressure adopted, 150 lb. was chosen because it gave slightly better results than at 140 lb. at only a slight increase in heating costs and about equal results with the 157 lb. runs. There was little difference in the nitrogen loss at 100 lb. and 160 lb. The loss of nitrogen from the wet cake was about 80 per ct. of the original 4 per ct., giving a nitrogen content of 0.8 per ct. in the wet cake, or 1.5 to 1.8 per ct. in the dried cake. About one-third as much organic matter was removed from the sludge by cold pressing as by heat treatment. Since writing the paper, some experiments had been made in submitting the waste liquor to a short period of anaerobic digestion, which resulted in a material reduction in the B.O.D. of the liquor.

R. W. Kehr

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## LABORATORY STUDIES OF CHEMICAL PRECIPITATION OF SEWAGE

By Edgar Whedbee and P. J. Alwin Zeller

Texas Engineering Experiment Station, *Bulletin* **44** (1937)

The effect of all factors including chemical used, hydrogen ion concentration, mixing and sewage characteristics was studied in this investigation. A series of experiments was run on six chemicals including ferric chloride, ferric sulphate, copperas, chlorinated copperas, filter alum and aluminum chloride. Each series of tests was run at various hydrogen ion concentrations from pH 2 to 13, the reaction being adjusted with sulphuric acid, lime or caustic soda. The sewage used in the tests was strong and highly variable. The average 5-day B.O.D. of the sewage was 370 p.p.m. and the suspended solids averaged about 510 p.p.m.

The results of the experiments with the above coagulants may be summarized as follows:

*Ferric Chloride.*—Using 4 g.p.g. of this coagulant without pH control, the results obtained were superior to plain settling. Poorer results are obtained as the pH is in-

creased above the neutral point while coagulation on the acid side is advantageous. It was found that ferric chloride free from ferrous was essential for the success of the process, that aeration did not improve coagulation, but that small doses of permanganate did, and that chlorine was not practical as a hydrogen ion control agent. Return of sludge improved coagulation and removals, while coagulation of settled sewage did not produce an effluent superior to coagulated raw sewage. With the pH adjusted to about 5.5 with acid and 2.0 to 2.5 g.p.g. of ferric chloride, 90 to 95 per ct. removal of suspended solids and 80 per ct. removal of oxygen consumed and 5-day B.O.D. were obtained. Ferric chloride was considered the best coagulant available.

*Aluminum Chloride.*—Proper coagulation can be obtained with this coagulant over a pH range from 5.5 to 9.0. Without pH control about 10 g.p.g. of $AlCl_3$ are required, with lime control about 5 g.p.g. and with acid control 2.5 to 5.0 g.p.g. Removals slightly lower than these obtained with ferric chloride may be expected with $AlCl_3$.

*Filter Alum.*—Filter alum is a satisfactory sewage coagulant over a pH range from 6.0 to 8.5. Removals of 80 per ct. suspended solids and 60 per ct. oxygen consumed and 5-day B.O.D. are obtained with 5 to 6 g.p.g. of alum. Coagulation on the alkaline side is more practical.

*Ferric Sulphate.*—The optimum results with ferric sulphate are obtained by pH adjustment with lime to 8.0 or 8.5. Two and one half g.p.g. of ferric chloride and 10 g.p.g. of lime will remove 80 per ct. of the suspended solids and about 60 per ct. of the oxygen consumed and 5-day B.O.D.

*Copperas.*—Without pH control or with pH adjustment on the acid side copperas is a poor coagulant. Copperas is apparently unable to flocculate colloidal matter in the acid range for the oxygen consumed and B.O.D. removals are no better than plain sedimentation. Optimum coagulation is obtained with copperas at pH 9.0 or above. About 10 g.p.g. of lime and 2.5 to 5.0 g.p.g. of copperas are required. Overdose of coagulant causes after-precipitation and may reduce removals.

*Chlorinated Copperas.*—With chlorinated copperas coagulation is poor at the neutral point but becomes better on both acid and alkaline sides until optimum points are reached at pH 5.5 and about 9.0 to 9.5. About 10 to 15 g.p.g. of sulphuric acid or 12 to 10 g.p.g. of lime are required to reach the optimum conditions with a chlorinated copperas dosage of 2.5 to 5.0 g.p.g. At these points removals of 80 to 90 per ct. suspended solids, 60 to 80 per ct. oxygen consumed and 70 to 80 per ct. 5-day B.O.D. may be expected. Doses of potassium permanganate assist coagulation with both copperas and chlorinated copperas.

Under the conditions at Dallas sodium aluminate was not a suitable coagulant. It was also found that while calcium chloride will coagulate sewage it may be best used to assist the coagulation of some other chemical such as ferric chloride. Experiments using chlorinated return sludge as a coagulant were also carried out. It was concluded that in view of the amount of chlorine used, and of the poor and erratic removals of oxygen consumed and B.O.D. the chlorinated sludge was not a practical coagulating agent.

C. C. RUCHHOFT

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## OZONE TREATMENT OF SEWAGE

BY FRANK R. THEROUX

Michigan Engineering Experiment Station, *Bulletin* 74, pages 12–19 (May, 1937)

The demonstration pilot plant included an ozone generator consisting of an air dryer, air compressor and ozonator; and sewage treatment units consisting of an ozone mixing tank, coagulation tank and settling tank. The ozone was applied at the rate of 43.5 lbs. per million gallons into an ozone mixing tank five feet in depth. The total detention period in the mixing and reaction tanks was about 20 minutes and the sewage was then settled for two hours. During part of the test the sedimentation tank effluent was passed through an upward flow sand filter. Analyses indicated an average removal

of 87.4 per cent suspended solids, and a 5-day B.O.D. reduction of 64.5 per cent without filtration. The filter increased the suspended solids removal to 95.6 per cent and the 5-day B.O.D. reduction to 85.1 per cent.

C. C. RUCHHOFT

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## THIRD BIENNIAL REPORT, 1935–1936, MICHIGAN STREAM CONTROL COMMISSION

By Milton P. Adams, *Chf. Eng.*, Lansing

The Third Biennial Report of the Commission gives a detailed and comprehensive account of the work by and under the Commission, including the Act under which it was created in 1929. Under the provisions of this Act, the Commission is charged with the responsibility of protecting the unpolluted waters of the State and of relieving those suffering gross injury. To accomplish the latter purpose without disrupting industries and municipalities established on a basis of unrestricted water use, means necessarily slow progress. Yet the need of clean recreational waters and protected water supplies is often greatest near the centers of population and industrial activity. Thus arises the most difficult problem in stream pollution control administration.

In paving the way toward a solution of its problems, the Commission calls upon and receives aid from various agencies, including the laboratories of the State Department of Health, the Institute of Fisheries Research, the Engineering Experiment Station at Michigan State College, and certain federal and national trade agencies. Close cooperation exists with the State Department of Health, which is charged by law with the approval of plans for municipal water and sewage plans in relation to the public health, the issuance of construction permits and supervision of plant operation. The Commission receives the aid of the U. S. Public Health Service on certain major pollution problems. The working staff includes the executive secretary-engineer, stenographer, sanitary engineer and two junior engineers. The annual expenditures since 1929 have ranges from $10,340 to $27,146. The estimated budget for 1937–1938 is $64,543, to finance increased activities.

In a condensed summary are listed sewage treatment plants in 50 municipalities with a total population of 654,469 in operation on January 1, 1935. New sewage treatment plants completed during the biennium number 21, serving 21 municipalities and a total population of 255,268. Sewage treatment projects under construction at Detroit are 8 in number, and will serve a total population of 1,789,973. Active projects under way are 17 plants, serving 24 municipalities with a total population of 120,561. Needed sewage treatment plants not yet under way are listed for 88 municipalities with a total population of 603,411. In addition is a list of industrial plants, including 1,508 milk and milk products factories and 1,400 oil wells, which discharge wastes into the waters of the state, through sewer systems or otherwise.

*Stream Pollution Surveys.*—The surveys of streams and rivers involve the collection and analysis of samples for dissolved oxygen, B.O.D., bacteriological, biological and other special information. River pollution charts are prepared, showing graphically the oxygen resources of a stream weighted against the oxygen demand and the "bacteriological load." Six rivers have been charted in this manner. Coastline pollution surveys, showing the bacteriological quality of waters along the various lakes, have

covered 900 miles of shore line, with 800 established sampling stations. The greater portion of this work, which has been devoted to the Great Lakes, was carried out in 1930–32 and the results have been published in a separate volume. Since 1933 lack or funds have necessitated curtailing this work.

*Stream Gaging.*—Records of stream flows are essential in pollution control work in order to show the ratio of dilution water to volume of wastes. Stream gaging was begun in Michigan in 1899 and the number of stations was increased to 20 in 1901–04. Because of lack of funds and adequate equipment, many of the long-time records have been impaired. Since 1930 stream gaging has been carried out in cooperation with the U. S. Geological Survey on a 50–50 basis, the State's expenditure for this work having reached $5,850 in 1936. The estimated cost for putting this work on a basis of maintaining 50 gaging stations would involve the allotment of $10,000 annually by the State.

*Saginaw Valley Work.*—In 1935 the State appropriated $15,000 for a study of the Saginaw Valley problem, including both the river and the bay. The study has been divided into three parts: (1) Saginaw Bay surveys; (2) River surveys and (3) Industrial wastes studies, including special studies of oil field brine wastes, which have become a major problem. In the surveys of the Bay, covering a total distance of about 7,000 miles by boat, an interesting feature of the work was the use of a conductivity cell for measuring in the field the concentration of chloride at different points, resulting from oil field brine pollution. Analyses of beet sugar factory wastes were made periodically throughout the 1935 campaign and cooperative experimental work on the treatment of these wastes was carried out with the industries during the same period.

*Stream Pollution Control.*—Municipal sewage continues to rate as the most widespread and serious factor in the pollution of Michigan waters. It is present in some northern streams of the State having high recreational values, as well as in the more heavily settled portions of the lower peninsula. Although water supplies have been protected by chlorination since 1913, little thought has been given until recently to the safety of the polluted waters for bathing and outdoor recreational pursuits. This condition has led the Michigan Department of Health to post warnings near waters considered as unsafe for bathing.

The past two years has seen the completion of 23 new sewage treatment plants. During the coming biennium, the Detroit and other projects should be completed, thereby bringing the State's percentage of sewage treatment from 19 per cent as of January 1, 1935 to about 80 per cent. All of the larger projects and most of the $26,000,000 sewage disposal outlay in Michigan during 1936–38, inclusive, is being made possible by P.W.A. and the initiative of public officials. Most of the P.W.A.'s accomplishment has dated from June, 1934, when a favorable Michigan Supreme Court decision on the 1933 Revenue Bond Law. In the Detroit area, the remaining sections of the Detroit River intercepting sewer are completed or under contract. Bids are soon to be completed on the Detroit treatment plant which, when constructed, will satisfy after many years the Federal Government's treaty with Canada. Following a Federal grant of $9,000,000 for completion of this $20,000,000 project, Wayne County has been active in submitting an application to the P.W.A. which will cover the remainder of the lower Detroit River problem.

*Industrial Wastes Control.*—The wide distribution of industries through the State has created varied pollution problems for the Commission. With a few exceptions, the past two years have seen little progress in the general field of industrial pollution control, owing in part to the effect of the depression. Among the industries producing wastes causing serious pollution problems are sugar refining, oil producing and refining, milk processing, canning, paper making, chemical manufacturing and tanning. Less is known about treatment and recovery measures for industrial wastes than for sewage, and the problems thereby presented are more difficult and diversified. Much can be accomplished by certain industries by recovery and re-use of process waters. By-product recovery, though seldom yielding a profit, frequently offers a means of materially reducing cost where treatment is required. Combining trades wastes with municipal sewage for treatment through municipal plants is in order where feasible. Pre-treatment at the industrial plant may be necessary, however, to avoid injury to sewage treatment

processes. When separate treatment of the waste is necessary, two general methods are available, namely, chemical and biological. Chemical treatment is particularly adaptable to wastes resulting from seasonal operations, and often can be applied to wastes not capable of biological treatment.

The outstanding industrial pollution problem in Michigan during the past two years has been the result of oil field development. This problem concerns largely the disposal of highly concentrated brine, which accompanies oil production. This brine is far stronger than sea water, averaging about 165,000 p.p.m. in chloride content. This colorless fluid, out of which crystals appear as it leaves the well, is almost 35 per cent solid matter. Calcium and magnesium salts included in the brine are responsible for the destructive hardness of water supplies contaminated with the brines. It has been estimated that every additional 50 p.p.m. of such hardness costs an additional $3.00 per million gallons for softening chemicals. Fish are threatened with destruction at concentrations of 3,000 to 5,000 p.p.m. and the resistance of trout to brine pollution is much less, about 500 p.p.m. The opening of new oil fields and extension of existing fields have resulted in increased injury to Michigan's water resources, both in extent and intensity. It is estimated that with a total production of 28,364 barrels of oil daily from 1362 wells, a total of 47,432 barrels of brine are produced, of which 26,240 barrels are returned to underground formations and 21,192 barrels are discharged to surface waters in the State. Although ponding is sanctioned as a temporary measure, the Commission states that the following measures are required: (1) limitation of brine production at the well; (2) utilization for dust laying and chemical production; (3) disposal of the residue to approve underground formations.

Beet sugar wastes have been the subject of study during the past two years, under a cooperative arrangement between a technical committee of the industry and the Commission. In cooperation with the Michigan State College Engineering Experiment Station a 100,000 gallon treatment plant has been constructed and as the result of experiments at this plant a 1,000,000 gals. per day plant has been installed, consisting of a continuous grit removal mechanism, sedimentation tank for continuous sludge removal and a vacuum filter for sludge drying. Summaries of the results are given.

Work on milk wastes has been carried out at the Engineering Experiment Station, several biological filters having been developed for experimental treatment at various industrial plants, following designs laid out at the Station. The design of these filters calls for 8 feet depth of stone graded in size from 1½ to 3 inches upon which the waste is applied continuously at a rate of 1 gallon per square foot per hour. Material increases in efficiency and economy over the biological filter have been demonstrated recently through a plant incorporating chemical precipitation and aeration with recirculation of sludge. Removal of about 90 per cent of B.O.D., with low cost of operation, indicates that this method may be generally applicable to the industry's waste problem.

Other waste treatment problems dealt with in the report are those of paper mills, tanneries and textile plants, as well as some other wastes principally from the canning industry. Cyanide waste problems have arisen in connection with automobile manufacturing. The treatment process adopted by the Chevrolet company is stated to set a standard for control of these wastes, though where amounts of the cyanide waste are small, oxidation in retention ponds is often adequate.

A complete bibliography of references to reports and other publications is given at the end of the report.

H. W. STREETER.

Combined wastes and sewage disposal plant at Herkimer, N. Y., using P. F. T. 28′ Floating Cover Digester and P. F. T. Flame Trap. Planned and constructed under supervision of Henry W. Taylor, Consulting Engineer, New York City.

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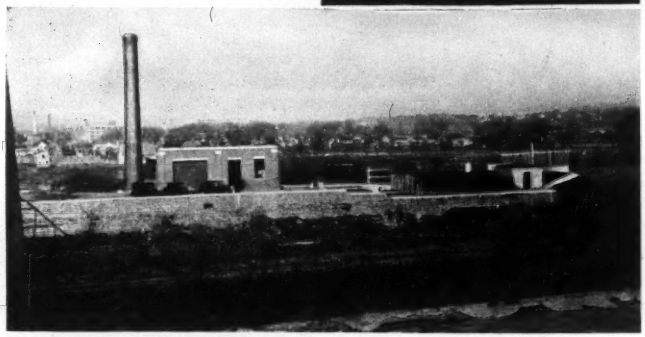

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New York State's Mohawk Valley communities have banded together into the Mohawk Valley Towns Association in order to foster progress in this area. This body presented the Village of Herkimer its 1936 Civic Enterprise Award, for progressiveness and public service in constructing a combined sewage works and refuse incinerator. Henry W. Taylor, Consulting Engineer of New York City, planned and constructed this project.

Comprehensive literature is available covering P. F. T. Floating Cover Digesters and other proved sewage treatment equipments including: Sprinkling Filter Plants, Screening Digesters, Rotary Distributors, Alternating Siphons, Clarifiers, Twin Tank Controls, Sludge Pumps, Flame Traps, Waste Gas Burners, etc.

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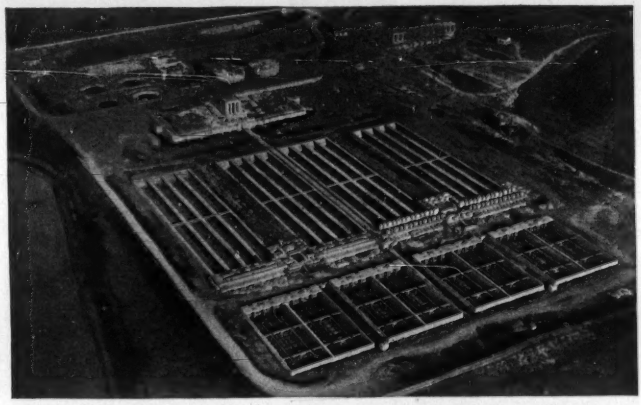

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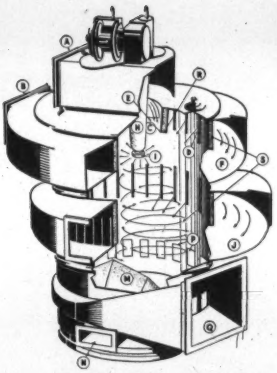

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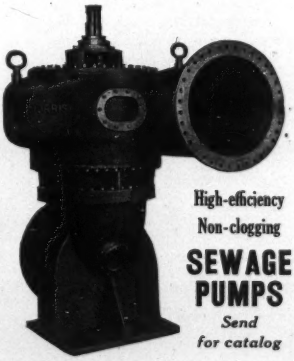

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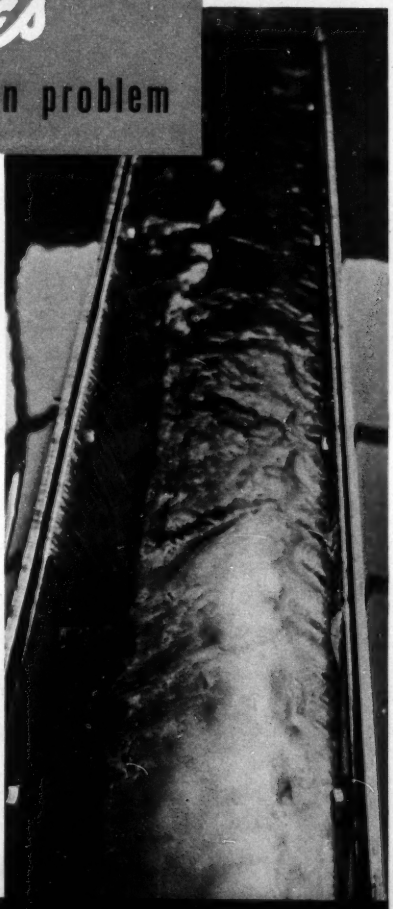

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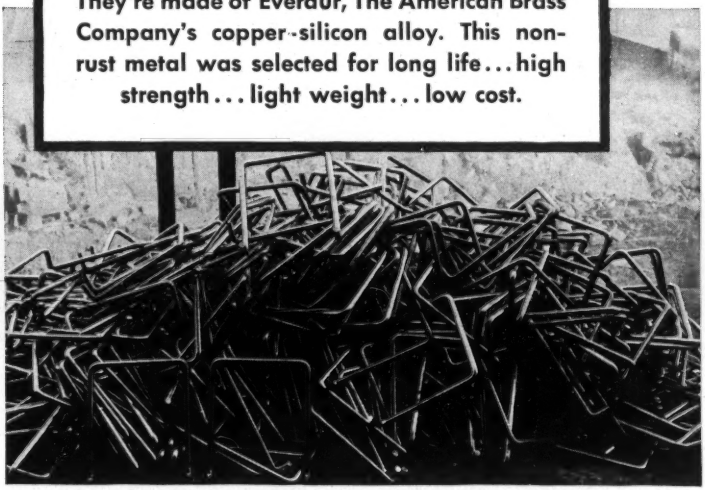

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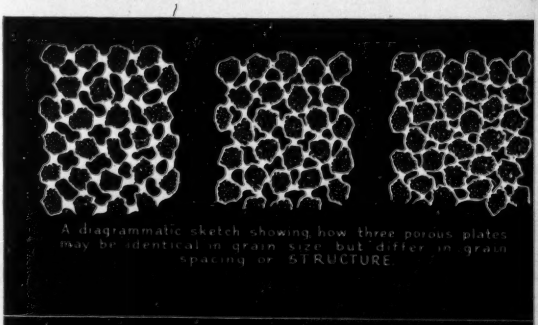
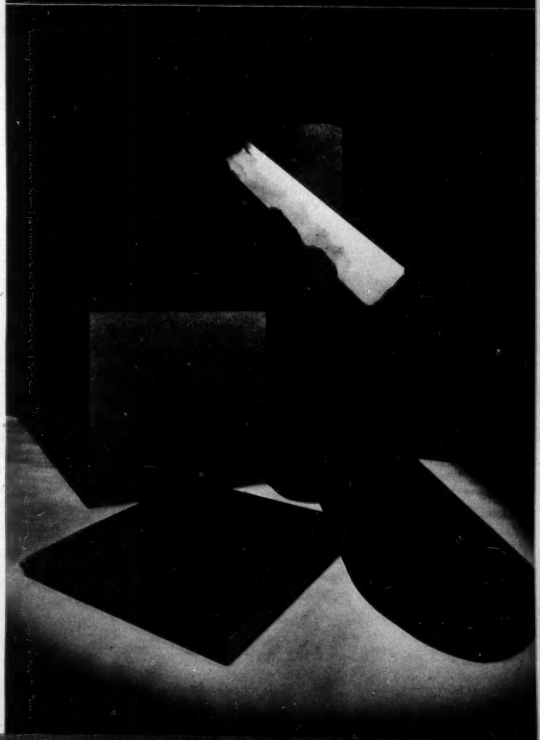


A diagrammatic sketch showing how three porous plates may be identical in grain size but differ in grain spacing or STRUCTURE



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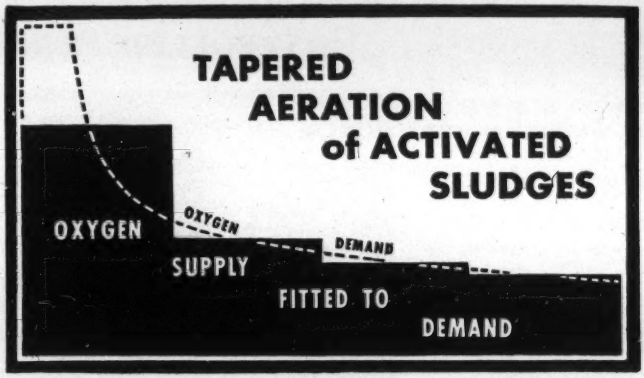


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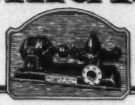

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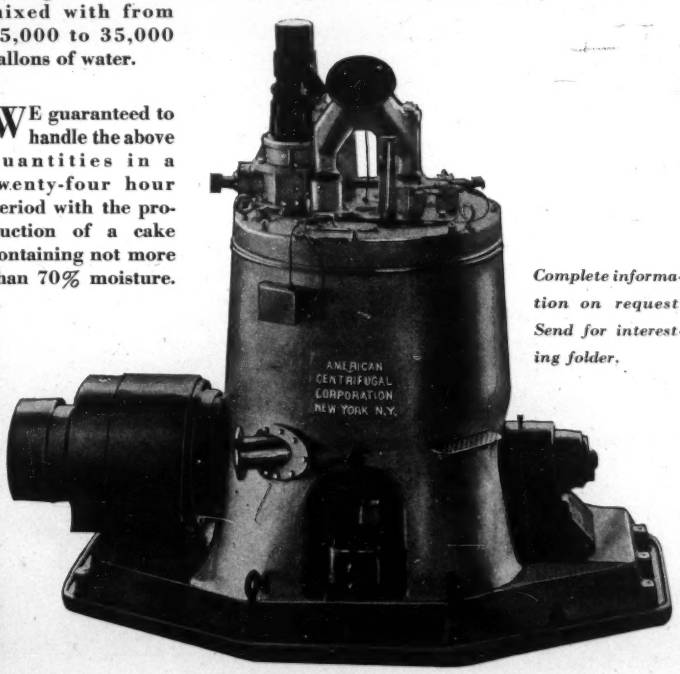


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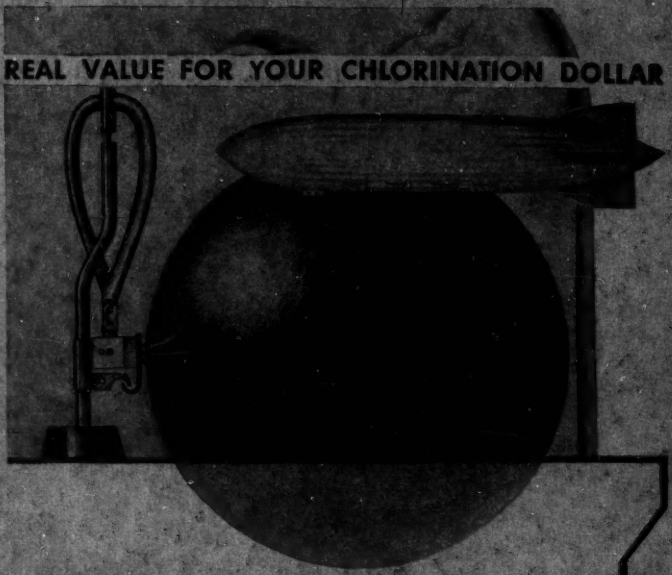

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